AN ABSTRACT OF THE THESIS OF

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Title: Small-Pebble and Heavy-Mineral Composition of Glacial Deposits in Northeastern Kansas

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Continental glaciation in Kansas was demonstrated beyond doubt more than a century ago. Deposition rather than erosion was the predominant effect of glaciation in Kansas. The composition of these glacial deposits was investigated and is described in this thesis.

Core samples from a buried valley in northeastern Kansas were provided by the Kansas Geological Survey. Subsurface samples from thirteen localities were analyzed for small-pebble (4-8 mm) and heavy-mineral (.0625-.125 mm) content. Fourteen samples were analyzed for pebbles and fifty-one samples were analyzed for heavy minerals.

Surficial samples were collected from along the buried valley and the glacial border zone. Samples from ten localities were analyzed for small-pebble and heavy-mineral content. Thirty-

seven samples were analyzed for pebbles and fifteen samples were analyzed for heavy minerals.

The samples were separated into their respective grade sizes by wet sieving. The small pebbles were identified by using a binocular microscope, counted, and put into the following categories: quartz, quartzite, felsic crystalline, mafic crystalline, limestone, chert, sandstone + shale, and ironstone.

The heavy minerals were identified by using a petrographic microscope, counted, and put into the following categories: opaque, amphibole, epidote, garnet, kyanite, pyroxene, rutile, sphene, spinel, tourmaline, and zircon.

Depositional environment is, aside from weathering, the most significant factor in determining the composition of the tills, sands, and gravels. The tills were deposited directly by glacier ice, and contain a considerable percentage of limestone plus sandstone and shale and of unstable heavy minerals. The sands were deposited in proglacial lakes, thus they underwent enough transportation to remove some of the limestone plus sandstone and shale and some of the unstable heavy minerals. The gravels have been deposited by outwash streams, and most samples have lost most of the limestone plus sandstone and shale and most of the unstable heavy minerals as a result of longer stream transportation.

SMALL-PEBBLE AND HEAVY-MINERAL COMPOSITION OF GLACIAL DEPOSITS IN NORTHEASTERN KANSAS

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CHAPTER I

INTRODUCTION

The existence of glaciers that advanced as far south as the northeastern corner of Kansas has given rise to the name "The Great Ice Age." This time period has come to be a synonym for the Pleistocene Epoch. Conclusive evidence (Frye and Leonard, 1952) shows that during several segments of Pleistocene time the rate of snow accumulation exceeded the rate of melting at two major areas in Canada. These areas of principal accumulation have been called the Keewatin center (west of Hudson Bay) and the Labradoran center. During the early Pleistocene, continental glaciers that originated in the Keewatin center expanded to such an extent that they reached into northeastern Kansas and eastern Nebraska (Frye and Leonard, 1952).

Continental glaciation in Kansas was demonstrated beyond doubt more than a century ago by the presence in till deposits of stones transported from distant sources, by the large size of these erratic or "foreign" boulders, and by the general character of deposits and surface features. The name "till" is generally used to designate deposits made directly by glacial ice, and "drift" includes a wider range of associated fluviatile, lacustrine, and other deposits. In the Kansas tills, pink "Sioux" quartzite is the most distinctive erratic and is found almost everywhere in the glacial materials. The nearest bedrock source of the pink quartzite found in the tills of Kansas occurs in southeastern South Dakota and northwestern Iowa. As this area is almost directly in line longitudinally from the inferred Keewatin center to northeastern Kansas, the presence of these pink quartzite boulders confirms the conclusion that the glaciers that invaded Kansas originated in that center (Frye and Leonard, 1952).

The maximum advance of the Kansan glacier was to a line several km south of the Kansas River; however, the ice front was probably stabilized for the longest period just north of the Kansas River (Davis, 1951). The west glacial drift border of Kansas is in Washington county west of the Little Blue River (Schoewe, 1939). Deposition rather than erosion was the predominant effect of the glaciers that invaded Kansas; deposition is characteristic of the terminal area of all glaciers (Frye and Leonard, 1952).

STATEMENT OF GOALS

During the past few years the Kansas Geological Survey (KGS) has conducted test drilling and sampling within buried valleys of northeastern Kansas. These valleys are filled by >100 m of clay, sand, gravel, and till (boulder-clay) deposited during the Kansan glaciation.

The sand and gravel deposits form important aquifers that supply groundwater for domestic and municipal use in northeastern Kansas. Lithology (rock and mineral composition) of glacial deposits has received only preliminary investigations limited to surficial exposures (Davis, 1951; Aber et al. 1982).

The goal of this research is to analyze sediment composition of core samples from buried valleys in Marshall and Nemaha Counties as well as surficial deposits in Doniphan, Atchison, and Shawnee Counties.

The research is significant because certain lithologic indicators may show the source and direction of ice movement into the region. The lithologic composition of valley-fill sediments has a significant influence on the chemical quality of groundwater contained in aquifers.

Both surficial and subsurface samples were analyzed for the 4-8 mm size of pebbles and the very-fine sand size of heavy minerals that occur in these glacial deposits. A better understanding of the lithologic characteristics of these deposits should come out of this research.

CHAPTER II

LITERATURE REVIEW

Three different lithologic units deposited by the glaciers will be discussed in this chapter. In chronological order from oldest to youngest they are: Lower Kansas Till, Atchison Formation, and Upper Kansas Till. The tills were deposited directly by the glaciers. The Atchison Formation was deposited in proglacial lakes during an ice retreat. These three formations along with associated unnamed deposits make up the Kansas Drift, a lithostratigraphic unit of group rank that represents the Kansan glaciation (Aber, 1985, 1987).

Two different ice lobes penetrated into northeastern Kansas (fig. 1). The first one, the Minnesota ice lobe, advanced southward through Iowa, into Missouri, and entered Kansas from the northeast. This advance deposited the Lower Kansas Till. The second ice lobe to enter Kansas was the Dakota ice lobe. It came from the Dakotas, across Nebraska, and moved into Kansas from the northwest (Aber, 1982, 1985).

Lower Kansas Till

The Lower Kansas Till is medium dark gray (N4). Where weathered, it has a yellowish-tan to brown color (Frye and Walters, 1950). The till consists of boulders, pebbles, and sand in a matrix of silt and clay. This till has been referred to as: Nebraskan, lower Kansan, or pre-Illinoian. The Lower Kansas Till has been recognized with certainty only in Doniphan, Atchison,

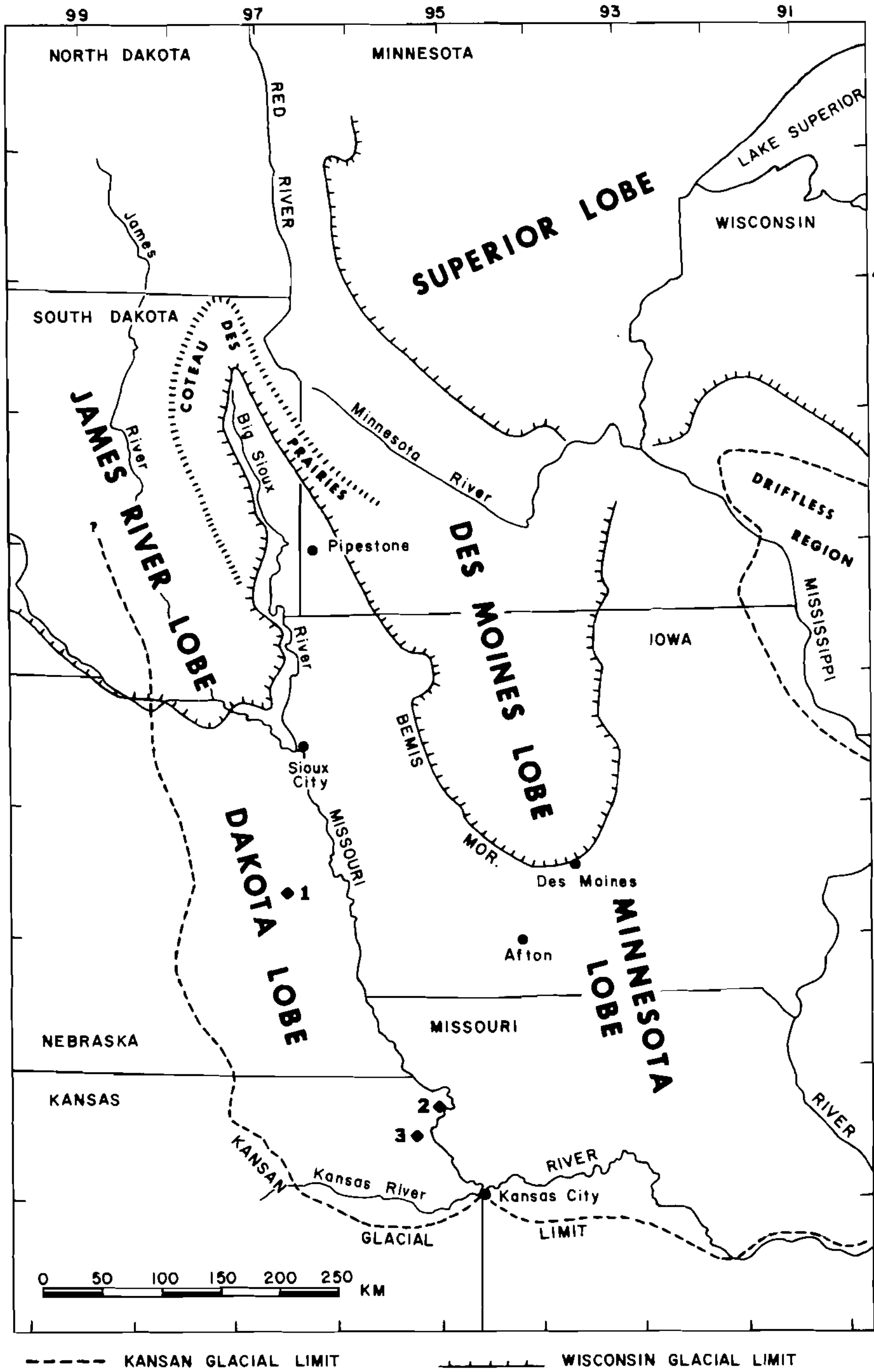

FIGURE 1. Map showing maximum extent of Kansan glacial ice lobes. 1= Cedar Bluffs site, 2= Wathena site, 3= Kansas Drift stratotype. Adapted from Aber (1985, fig. 8).

and Brown Counties in the extreme northern part of the State, and surface exposures are restricted to the Missouri Valley bluffs in Doniphan and Atchison Counties (Frye and Leonard, 1952). The till has also been recognized in Nemaha County from test well drilling.

Atchison Formation

After the initial ice advance, the Atchison Formation was deposited. The Atchison Formation is only slightly younger than the lower till. At some localities till interfingers with water-laid sands. This suggests that the Atchison was deposited as outwash and lacustrine deposits in proglacial lakes produced by the advancing glacier (Frye and Leonard, 1952). The Atchison Formation consists of silt, sand, and some gravel. The formation is found in surface exposures in Atchison County, as well as in a major buried valley that extends from southeastern Marshall County, across southern Nemaha and northeastern Jackson Counties, through central Atchison County, to the Missouri valley.

Upper Kansas Till

The second glacial advance deposited the Upper Kansas Till. This till is moderate to dark yellowish brown (10 YR 5/4, 4/2). Other than color, the two tills are similar (Aber, 1985).

The Upper Kansas Till includes the deposits made directly by the Kansan glacier and some water-laid sediments interstratified with the till. It does not, however, include the proglacial silts, sands, and gravels deposited in front of the advancing glacier or the outwash deposits from the retreating glacier (Frye and Leonard, 1952).

The Upper Kansas Till occurs in the state over much of the area north of the Kansas River and east of the Little Blue River. Here, Upper Kansas Till, which constitutes the predominant surface material, is extensively exposed in road cuts and natural exposures, except in parts of Brown and Doniphan Counties where it is mantled with thick loess. In the part of the area eastward from central Marshall County and eastern Pottawatomie County little bedrock is exposed and the till is as much as 90 m thick. At a few localities the till and the Atchison Formation have a combined thickness of approximately 120 m (Frye and Leonard, 1952).

The area of thick Upper Kansas Till terminates abruptly toward the west some distance within the glacial boundary. The deep accumulations of till are judged to have been importantly influenced by the bedrock surface over which the glacier advanced. A pronounced bedrock sag extends eastward across southeastern Marshall County, southern Nemaha County, northeastern Jackson County, and west-central Atchison County (Frye and Leonard, 1952).

Westward from central Marshall County, the till is generally thin and discontinuous. It is exposed west of the Little Blue River on the uplands in Washington County. Near the Nebraska state line the westernmost exposure of till in the State occurs in road cuts in Washington County (Frye and Leonard, 1952).

Southward from northern Jackson County the till thins toward the Kaw Valley and at many places along the north valley wall has been removed by erosion. Exposures of till south of the Kansas River are rare and the till that occurs on the uplands is thin and discontinuous. At a few places in northern Wabaunsee County and northwestern Shawnee County there are surface concentrations of glacial boulders, but evidence indicates that the till, nevertheless, is relatively thin (Frye and Leonard, 1952).

Drift Composition

Davis (1951), in the course of his studies on the lithology of various sand and gravel deposits in northeastern Kansas, analyzed the 4 to 8 mm size fraction of the Kansas till. He made the following statement as a result of this study (Davis, 1951, pp. 183, 187):

> ... the lithology of rock fragments in the till varies considerably; however, all unleached samples retained the same general characteristics. Fragments of pebble size and larger constitute less than 5 percent of the volume of the samples.

On the basis of 61 pebble analyses from 29 localities in northeastern Kansas, Davis was able to recognize significant differences in deposits derived from several sources. He stated the following conclusions (Davis, 1951, p. 191):

> ... gravel in unleached Kansas till and in the unleached outwash associated with the till varies considerably in lithology from one locality to the next. However, both retain the following characteristics in the 4 to 8 mm grade size: (a) more than 70 percent of the pebbles are derived from local rocks; (b) limestone is the most abundant rock; (c) granitic rocks are the most abundant

erratics; (d) pink quartzite constitutes less than 2 percent of the sample; and (e) the granitic group approximately equals in abundance the combined pink quartzite, miscellaneous metamorphics, and dark igneous groups.

Other than the study undertaken by Davis (1951), little has been done on the lithology of glacial deposits in northeastern Kansas. Davis studied surficial deposits only. The clay mineralogy of the Lower Kansas Till and Upper Kansas Till from Doniphan and Jefferson Counties was examined by Tien (1968, 1969).

There is little doubt that the chert fraction of the sub-till gravel in Atchison and Doniphan Counties originated in the flinty limestones found to the west in the Flint Hills and the Herington Limestone. The residual chert pebbles were moved into the northeastern part of Kansas by eastward flowing streams throughout Tertiary time. With the advent of glaciation, stream deposits of predominantly chert gravel were picked up and incorporated with glacial outwash. Deposition of the Lower Kansas Till tended to protect the sub-till gravel from subsequent erosion (Conrad, 1964).

CHAPTER III

METHODS AND PROCEDURES

Collection Sites

The core samples were provided by the Kansas Geological Survey. These samples are from a major buried valley (can also be referred to as a preglacial drainageway) that trends across Marshall and Nemaha Counties (fig. 2) and may be up to 5 km wide (Denne et al. 1982). Core samples were collected in December of 1986 (see Appendix A).

Surface samples have been collected from just west of the City of Atchison, Atchison County, Kansas, along the south side of White Clay Creek. Site No. 1, (AT-1) is located in NW 1/4, Section 10, T6S, R20E (fig. 3). Schoewe (1938) gave the earliest description of this exposure:

> ... west of Atchison, is a series of excellent exposures of glacial deposits. ... two distinct tills are present. The lower till is a typical unaltered or fresh, dark gray to blue compact boulder clay, as much as 20 feet thick. Its upper surface is irregular. The upper till, from 10 to 15 feet thick, is separated from the lower one by 50 feet or more of stratified sand. This till in contrast to the lower one is brown in color, and is very stony ...

Recently, Aber (1985) has designated this site as the Kansas Drift stratotype. The Kansas Drift is a lithostratigraphic unit of group rank containing three formations: Upper Kansas Till, Atchison Formation, and Lower Kansas Till.

Other samples have been collected from Atchison No. 2 (AT-2) which is located on the center line between the SW 1/4 and SE

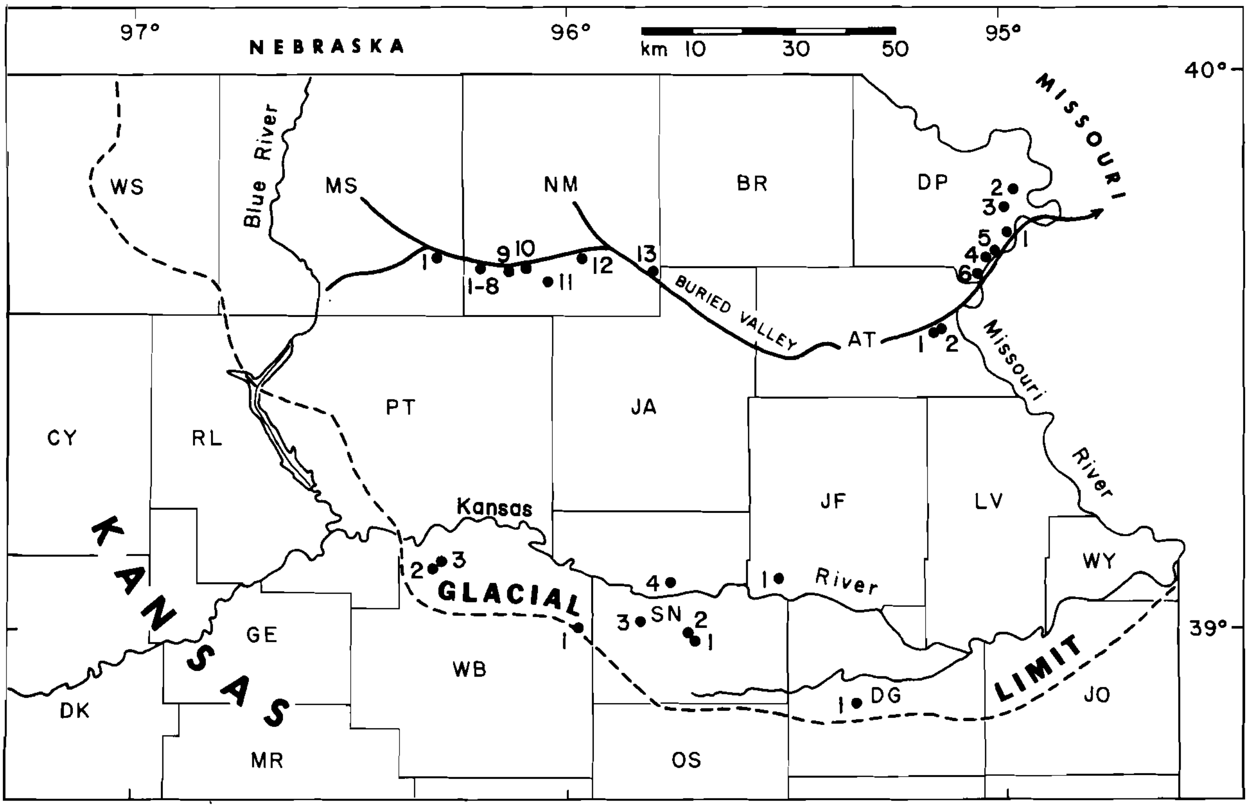

FIGURE 2. Map of northeastern Kansas showing the glacial border zone, and the buried valley from which surficial and subsurface samples were collected.

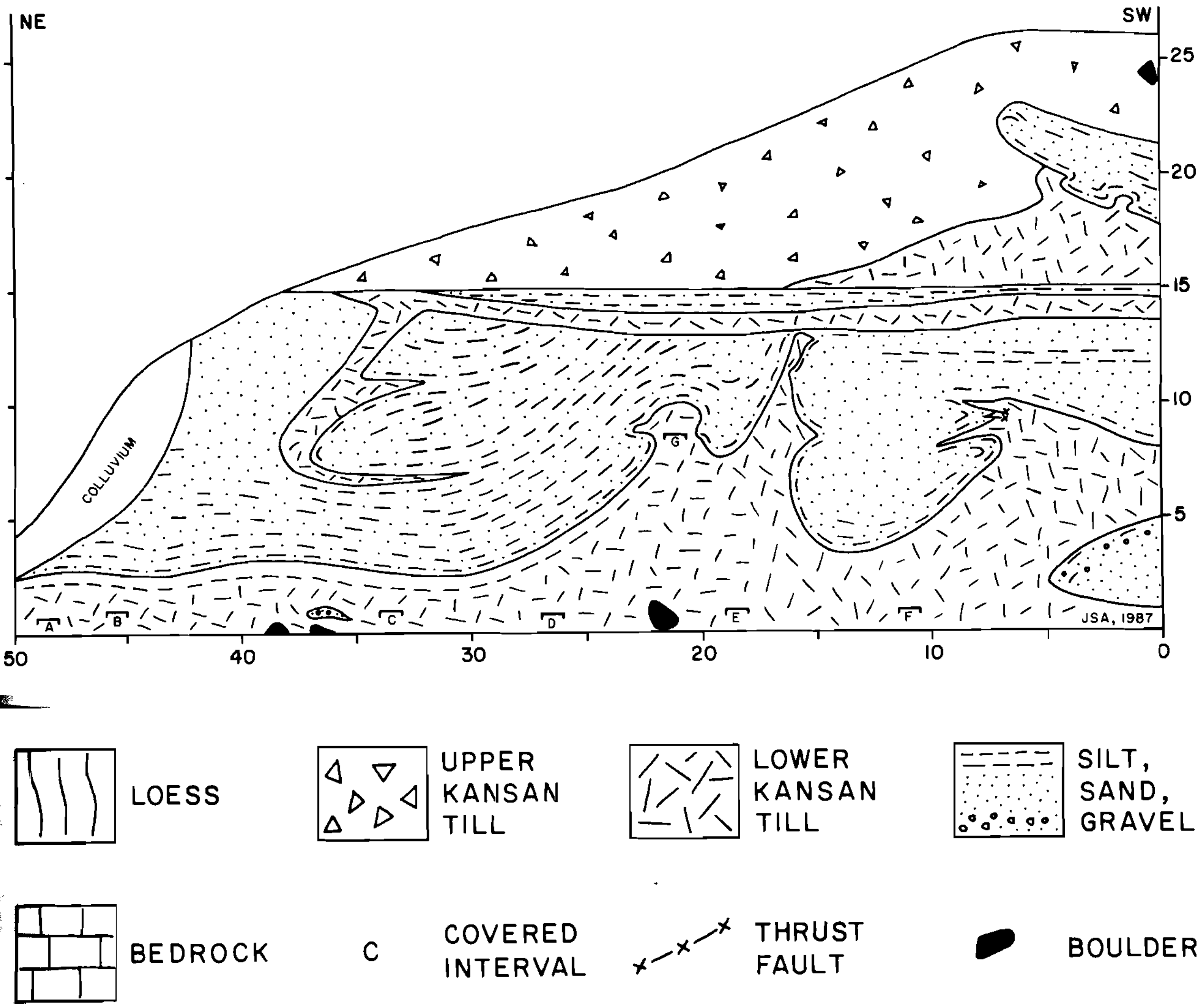

FIGURE 3. Kansas Drift stratotype as it appeared in 1987. Lower Kansas Till (below) is intruded up into Atchison Formation sand (middle), which is overlain by Upper Kansas Till (top). Scale in meters.

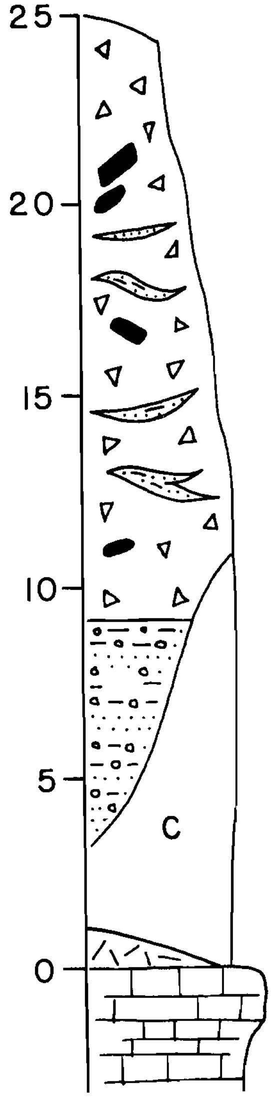

FIGURE 4. Atchison No. 2 section of Kansas Drift. Symbols same as Fig. 3. Adapted from Aber (1985, fig. 4). Scale in meters.

1/4, Section 2, T6S, R20E (fig. 4).

Surface samples have also been collected from south of Wathena (DP1, fig. 2), in Doniphan County, in Section 33, T3S, R22E. This exposure is dominated by Lower Kansas Till; samples were collected in December of 1986 (fig. 5).

Surface samples were collected in October of 1987 from a gravel pit in north-central Shawnee County. This is the Menoken Terrace stratotype, and is located in SW1/4, Section 9, T11S, R15E. These are water-laid outwash deposits, and this site is designated as SN4 (fig. 2).

Laboratory Technique

The subsurface and surficial samples were separated into different grade sizes by wet sieving: (1) small pebbles (4-8 mm) and (2) very fine sand (.0625-.125 mm). The small pebbles were counted for each sample into the following categories: quartz, quartzite, felsic crystalline, mafic crystalline, limestone, chert, sandstone and shale, and ironstone.

The heavy mineral composition from the very fine sand was analyzed. Bromoform liquid with a density of 2.85 g/ml was used to separate the heavy minerals from the light minerals. Heavy minerals have a density greater than bromoform.

The equipment for the heavy mineral separation consisted of a ringstand, a separatory funnel with pinchcock, a lower funnel with filter paper, and a beaker to collect the bromoform below the lower funnel. The bromoform was poured into the separatory

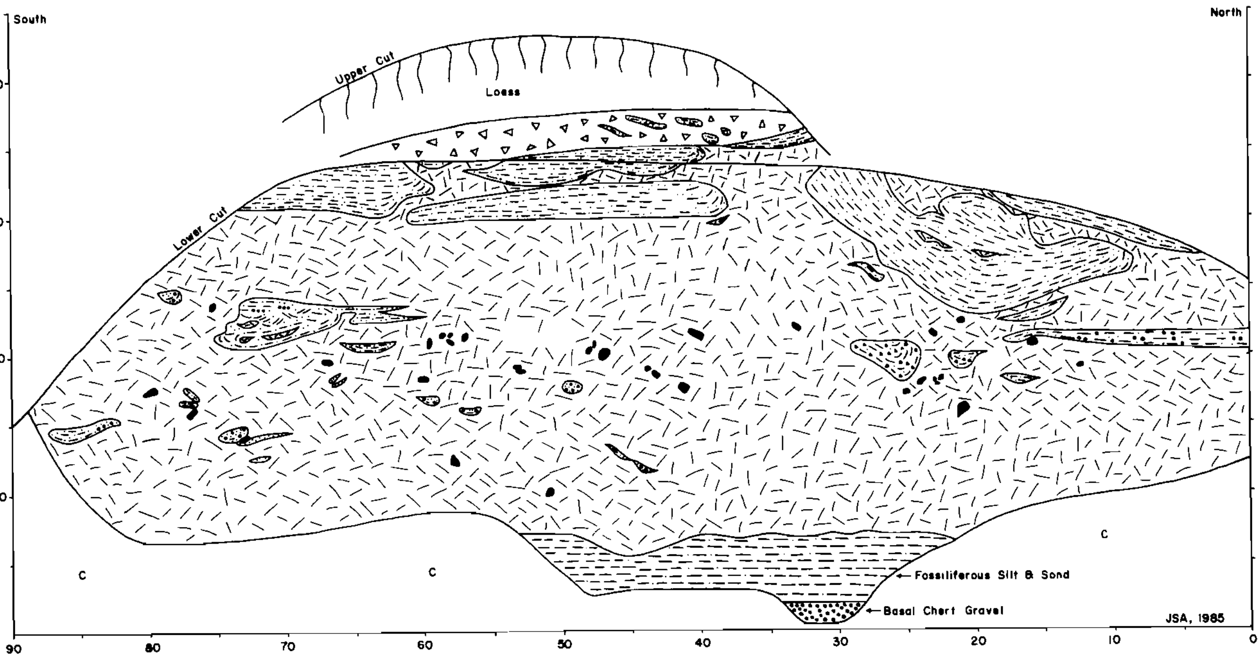

FIGURE 5. Wathena No. 1 section of Kansas Drift, as it appeared in 1985. Predominantly Lower Kansas Till. Symbols same as Fig. 3. Scale in meters.

funnel with the pinchcock turned so as not to allow any bromoform to pass through. The sand from each individual site and number was poured into the separatory funnel and stirred with a glass rod. The sand was allowed to sit for at least twenty minutes, and stirred again.

After a few more minutes, the pinchcock was opened to allow the heavy minerals to collect in the filter paper in the lower funnel. Care was taken not to allow any of the lighter minerals in the separatory funnel to pass into the filter paper. Once all the bromoform from the filter paper had drained into the collection beaker below the lower funnel, the heavy minerals in the filter paper were placed at the back of the hood. The filter paper left the bromoform very clear, so it was used again.

At this time, the lighter minerals had to be removed from the separatory funnel. A new piece of filter paper was placed in the lower funnel. The pinchcock of the separatory funnel was opened, allowing the lighter minerals to pass into the filter paper, and the bromoform to pass into the collecting beaker below. The lighter minerals were then discarded.

While the heavy minerals were drying under the hood, the individual samples were placed in beakers that had the sample number written on it. Once the samples were dry, they were put into small plastic bottles that had labels on them.

To aid in initial identification, the heavy mineral grains from representative samples were placed on a slide and immersed in a drop of liquid of known refractive index. A series of librated liquids ranging in refractive index from 1.41 to 1.80 s used. These liquids cover the refractive index range of most the common minerals. This is somewhat a trial and error method d involves comparing the refractive index of the unknown ineral with that of a known liquid. In this manner all heavy inerals were recognized, so that counting of mounted samples ould be done quickly.

Permanent mounts on petrographic slides were made before the dentification process took place. An epoxy resin and hardener ere mixed in equal amounts and placed in the middle of the lides. A small wood stick was used to make sure the epoxy was ell mixed. When the epoxy was in place, the heavy minerals were carefully placed on the epoxy. A cover slide was then placed over the epoxy and heavy minerals. The number of the sample was written on the slide at this time. The slides were handled very carefully as it takes a few hours for the epoxy to completely harden. Sixty-six slides were made for the surface and subsurface samples.

Once the heavy minerals were separated and mounted, they were identified and counted using a petrographic microscope. The petrographic microscope uses polarized light to reveal certain optical properties. In most cases these properties characterize a mineral sufficiently to permit its identification.

CHAPTER IV

SMALL-PEBBLE AND HEAVY-MINERAL IDENTIFICATION

Small Pebbles

The pebbles were identified using a binocular microscope. In the early stages, the microscope was used frequently. As the pebbles became more familiar, the microscope was used less frequently. The pebbles were classified into eight separate categories. The first four categories are erratic, or foreign, to this region: (1) quartz, which includes all fragments of coarsely crystalline quartz, (2) quartzite, which is distinctive of glacially transported material, generally either pink or white, (3) felsic crystalline, entailing mostly coarse-grained light igneous rocks, and (4) mafic, including diorite, gabbro, basalt, and other dark rocks.

The next four categories are composed of material that is commonly found in this region: (5) limestone, which is principally from local Permian and Pennsylvanian strata, (6) chert, including all cryptocrystalline quartz, (7) shale + sandstone category, including shale, sandstone, siltstone, conglomerate, and coal, and (8) ironstone, including limonite, marcasite, hematite, and pyrite. Other than counting the ironstone category, little else was done with it, because it is simply other rocks and minerals that have been altered to iron oxide by weathering or diagenesis.

Fifty-one samples containing small pebbles were counted. The tal number of pebbles counted was >13,500, with an average of 5 pebbles per count (see Appendix B).

avy Minerals

The heavy minerals were identified using a petrographic icroscope. With the aid of a mechanical stage, at least two undred grains were counted on each slide, with a minimum of one undred non-opaque grains. The two major categories of heavy inerals are opaque and non-opaque. The opaques include agnetite, ilmenite, hematite, limonite, pyrite, and marcasite. hese can only be identified by using a reflected-light icroscope. The microscope used in this research operates with efracted light, therefore all the opaques are classified and ounted simply as opaques.

The non-opaque heavy minerals were separated into four different categories. The first, isotropic, are minerals that turn dark when the analyzer, or lower nicol on the microscope, is pushed in or turned. Isotropic minerals are in the isometric crystal system. Garnet is usually colorless with high relief, and a refractive index of 1.76-1.94. Garnets were very abundant in many samples. Spinel can be colorless, but is usually a very pale pink. Spinel has high relief, with a refractive index of 1.72-2.05.

The second category are those that are anisotropic (let light pass through when the analyzer is in) and colorless. Kyanite shows first-order interference colors which are grayish very pale blue with the analyzer in. Kyanite can show parallel inclined extinction when lined up with a north-south or east-est cross nicol. It shows pleochroism, which is a color ange as the mineral is rotated on the microscope stage. Kyanite ows moderately high relief, and has a refractive index of 1.71-.73. Generally, kyanite was not found in any abundance. Zircon as parallel extinction and no pleochroism. It shows high relief nd a refractive index of 1.93-1.99. Zircons were very abundant n most of the samples.

The third category is those minerals that are anisotropic, colored, and non-pleochroic. Sphene is pale yellow or brown with very high relief and a refractive index of 1.90-2.00. It shows incomplete extinction and was rarely found in the research. Augite, which is a pyroxene, is pale grayish green with a moderately high relief and a refractive index of 1.67-1.74. In some samples pyroxene was a major constituent, but in others it was rare. Epidote is both non-pleochroic and pleochroic, but it is discussed in the next paragraph because it is more commonly pleochroic.

The fourth category is those minerals that are anisotropic, colored, and pleochroic. Epidote is pale greenish yellow, and very colorful with the analyzer in. It has moderately high relief, with a refractive index of 1.72-1.78. Epidote was very abundant in some samples, but rather rare in others. Rutile is dark red and shows weak pleochroism. It has parallel extinction although it is difficult to see at times. Rutile shows very high lief and has a refractive index of 2.60-2.90. In most samples t was rarely found. Hornblende, which is an amphibole, is ownish green or more commonly bluish green. It shows strong leochroism, moderately high relief, and has a refractive index f 1.62-1.72. Hornblende shows nonparallel extinction and was bundant in some samples, but rare in others. Tourmaline was llow on rare occasions, but was usually seen as dark brown. It hows strong pleochroism, and parallel extinction. Tourmaline has oderately high relief and a refractive index of 1.62-1.69. In any samples it was rare, but very abundant in others.

Sixty-six samples containing heavy minerals were counted. The total number of minerals counted was >17,650, with an average of 268 minerals per count (see Appendix C).

CHAPTER V

RESULTS OF COMPOSITIONAL ANALYSIS

Small Pebbles

Fifty-one samples * were counted in this research and are plotted on a ternary diagram (fig. 6). Of the total count, there are nineteen gravels, eight sands, and twenty-four tills. Two of the component points, LS+SS/SH and chert, were chosen for their overall abundance in many of the samples. The exotic component (quartz + quartzite + felsic + mafic) was chosen because it contains the glacially derived material. These three components generally represent >90% of pebbles in each sample.

Over half of the gravel samples are dominated by chert, with twelve samples having greater than 50% chert. Seven samples have less than 20% chert. All of the gravels have less than 50% exotic composition. The sand samples show an intermediate range, with three samples having less than 20% chert, four having between 20% and 50% chert, and one sample having greater than 50% chert. All but two of the sands have less than 50% exotic composition. The till samples are dominated by LS+SS/SH, with twenty-one having greater than 50% LS+SS/SH. All of the tills have less than 20% chert, and all but two samples have less than 50% exotic composition.

* Samples 25-51 are results of previous study by Aber in 1981 and 1985.

[He]avy Minerals

Heavy-mineral data are plotted on three ternary diagrams for [g]ravel (fig. 7), sand (fig. 8), and till (fig. 9). Two of the [en]d-member components, garnet and zircon, were chosen for their [o]verall abundance in many of the samples. The third component, [A]m+Ep+Py+Tr, was chosen because these four minerals together are [m]ore abundant than any other combination of minerals (excluding [z]ircon and garnet) that were found in the samples. These three [c]omponents generally represent >90% of non-opaque heavy minerals [i]n each sample.

Fifteen gravel samples were counted in this research; four of the gravel samples are from surficial exposures, eleven are from the subsurface. All gravel samples except one contain between 10% and 40% garnet. All fifteen samples have less than 50% zircon, and are between 15% and 63% Am+Ep+Py+Tr in composition.

Twenty-seven sand samples were counted in this research; seven of the samples are from surficial exposures, twenty from the subsurface. Six of the surface samples contain between 10% and 40% garnet. All of the surface sands have less than 50% zircon, and are between 15% and 63% Am+Ep+Py+Tr in composition. All of the subsurface sands except one contain between 10% and 40% garnet. All subsurface sands have less than 50% zircon. Four of the subsurface sands have greater than 63% Am+Ep+Py+Tr in their composition.

Twenty-four till samples were counted in this research; four

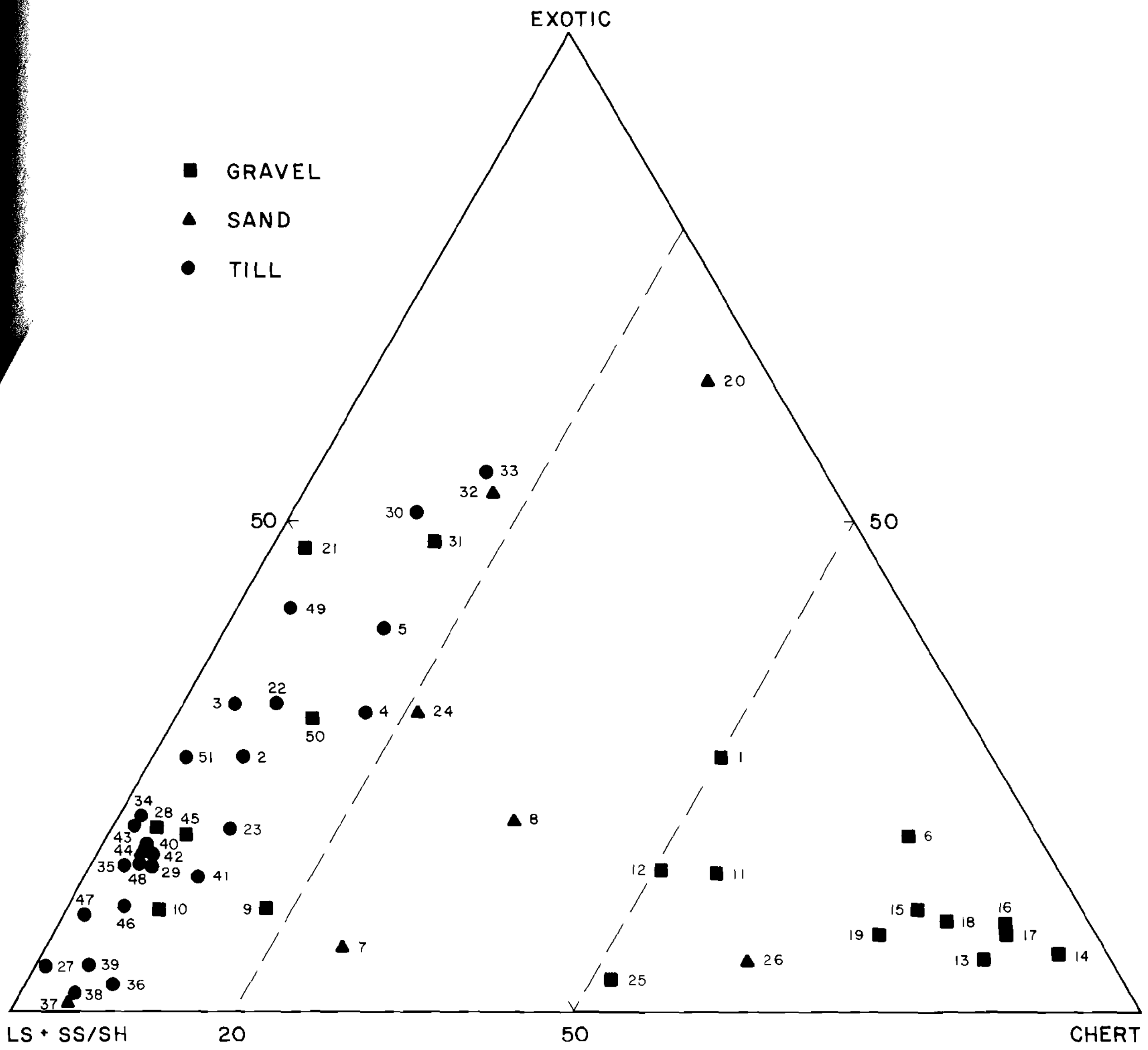

FIGURE 6. Ternary diagram showing distribution and composition of small pebbles for the sediment types of Kansas Drift. End-member components are normalized to 100%.

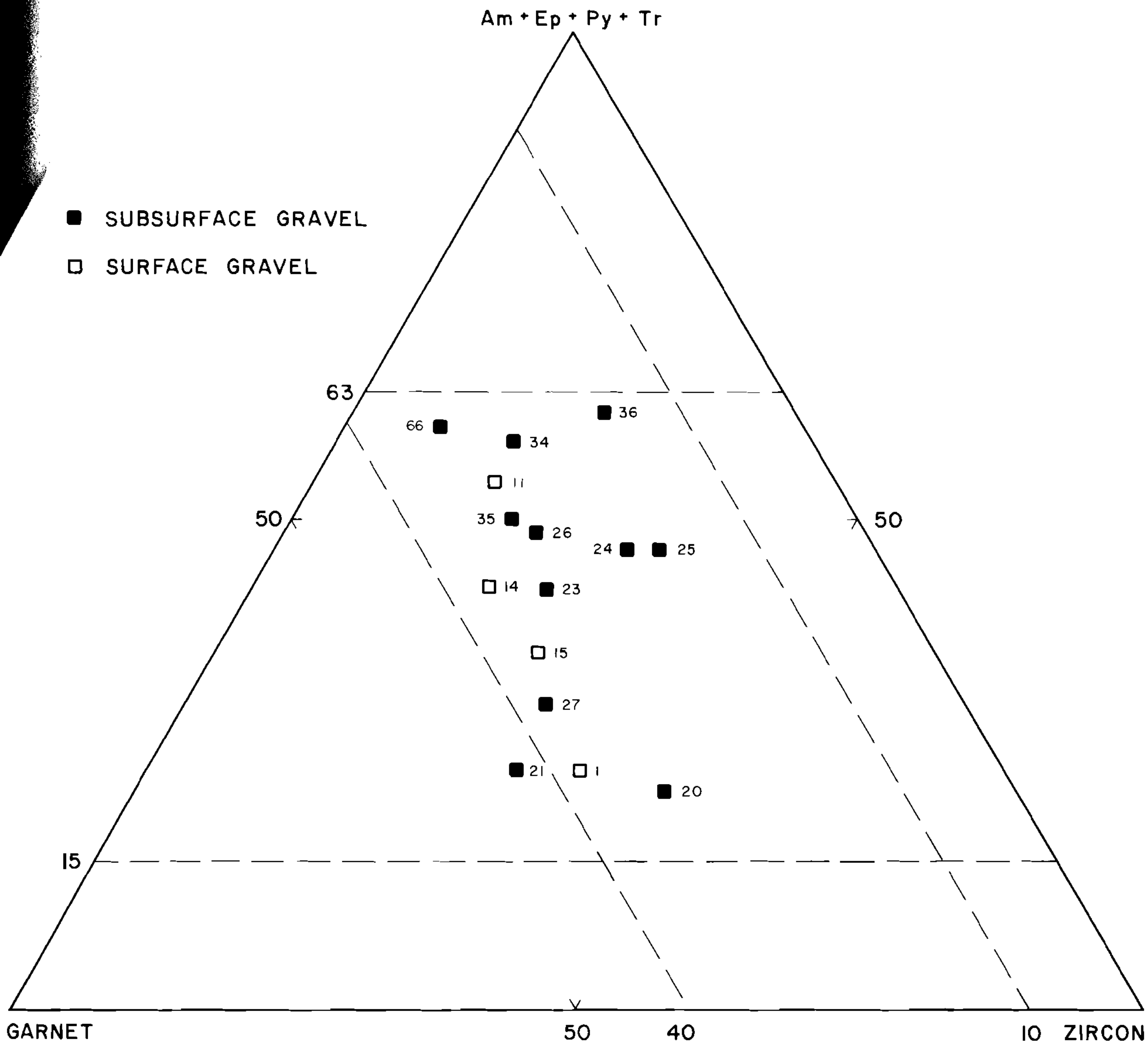

FIGURE 7. Ternary diagram showing distribution of heavy minerals from surface and subsurface gravels. End-member components are normalized to 100%.

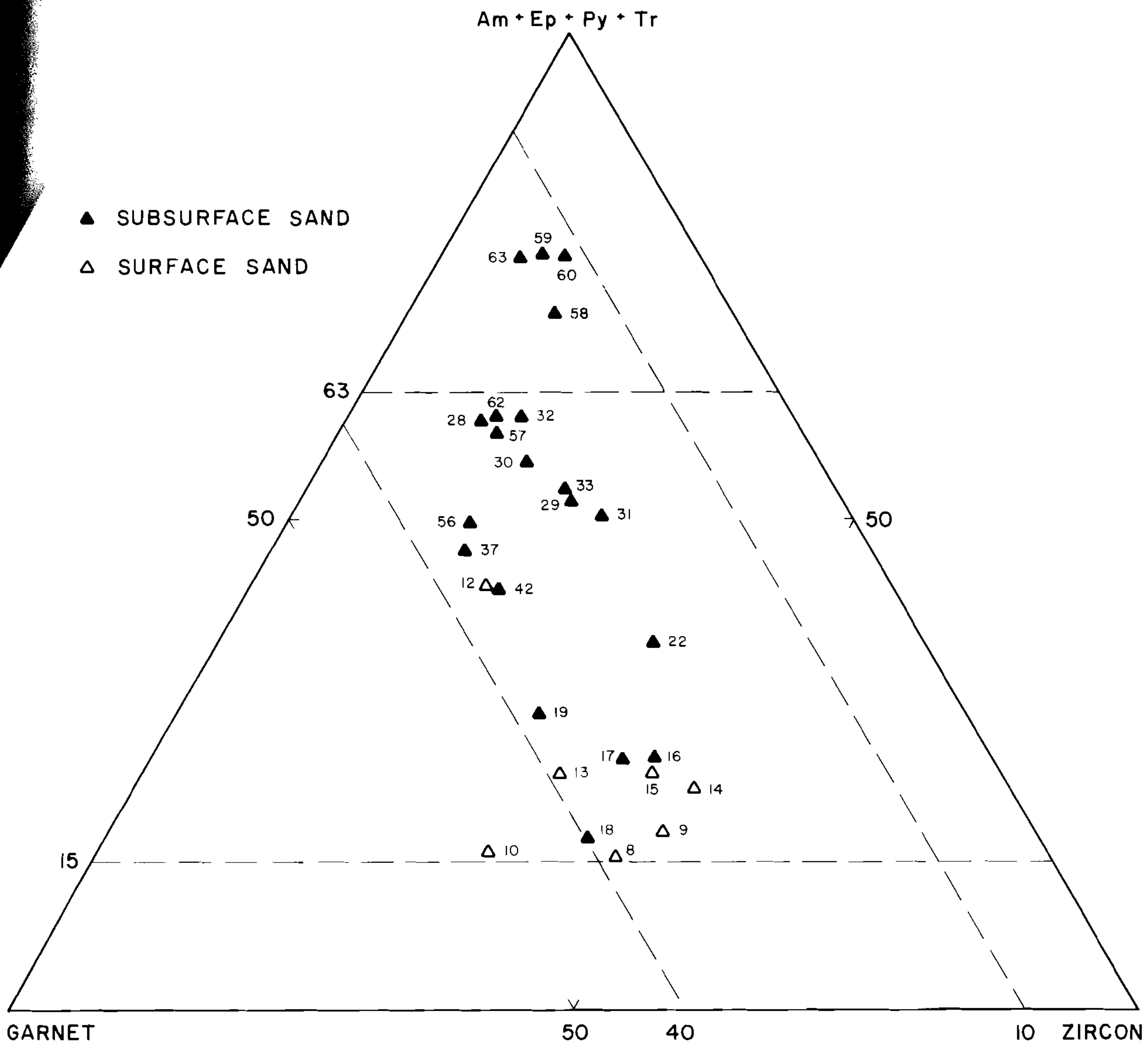

FIGURE 8. Ternary diagram showing distribution of heavy minerals from surface and subsurface sands. End-member components are normalized to 100%.

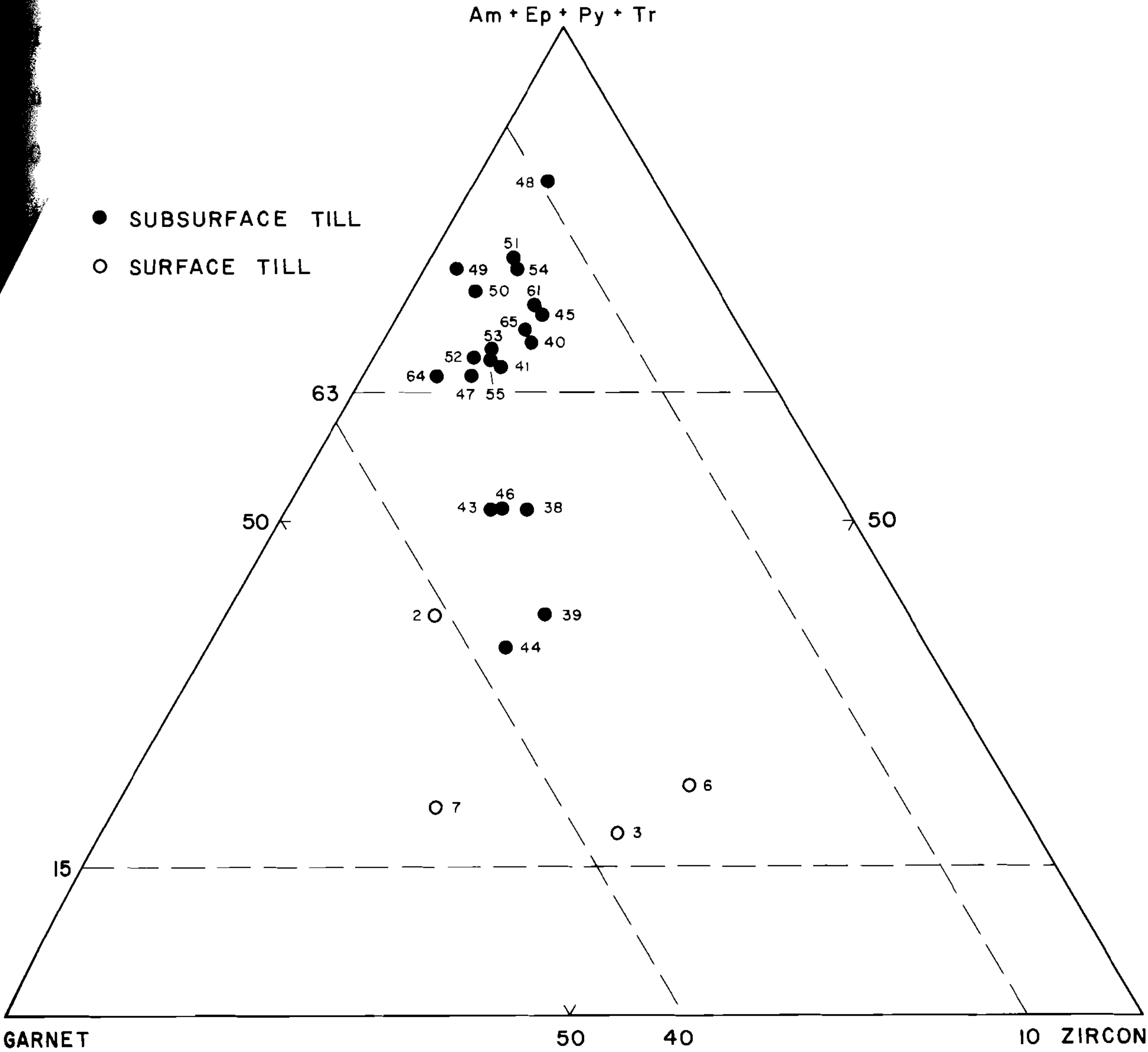

FIGURE 9. Ternary diagram showing distribution of heavy minerals from surface and subsurface tills. End-member components are normalized to 100%.

f the samples are from surficial exposures, twenty from the ubsurface. Two of the surface samples contain between 10% and 0% garnet, two have greater than 40% garnet. All of the surface ills have less than 50% zircon, and are between 15% and 63% in m+Ep+Py+Tr. All of the subsurface tills except one contain etween 10% and 40% garnet. All subsurface tills have less than 0% zircon. Fifteen of the subsurface tills have greater than 63% m+Ep+Py+Tr in their composition.

CHAPTER VI

INTERPRETATION OF RESULTS

Small Pebbles

From Fig. 6 one can quickly recognize a general trend in the small-pebble composition of the gravels, sands, and tills. All of the tills are in the area of <20% chert. A few sands and gravels fall in this area also, but till is the dominant sediment type. The sands fall into an intermediate area, between 20% and 50% chert by composition. Surface sands as well as a subsurface sand, 20, are represented. The gravels predominantly have a composition of >50% chert. A few samples have more LS+SS/SH than chert. Other than gravels, the only other sample with >50% chert is 26, which is a pebbly sand.

In order to interpret why the samples plot as they do, five different factors will be examined: (1) geographical location, (2) stratigraphy, (3) depth, (4) weathering effect, and (5) depositional environment.

The geographical location for gravel samples 11 and 12 is from Marshall County. The location for gravels 13-19 is from essentially the same place in Nemaha County. Other than these gravels, there is virtually no evidence to support the idea that geographical location is a major factor for the plots of the remainder of the samples.

Stratigraphy proves to be a minimal factor, if any at all. Other than the gravels mentioned earlier and some of the rficial tills, no real conclusions can be drawn from this. pth proves to be a minimal factor also. The weathered samples ot at or above the 50% exotic line, but some other near-surface mples plot close to samples from considerable depth.

Weathering proves to be fairly significant. Samples 30 to 33 e surface material and contain no limestone. Sample 20 is from ine sand at 6.7 to 6.9 m in depth, and has only three limestone ebbles. These samples plot as they do because they are products f weathering. All are higher than or nearly on the 50% exotic ine. The exotic component consists of material that does not eather easily. This is certainly reason enough to believe that eathering has a considerable influence on the composition of these samples.

Depositional environment is, aside from weathering, the most important factor. The tills were deposited directly by glacier ice. Other than the weathered samples, all the tills contain a considerable percentage of LS+SS/SH. The tills have been altered very little by the action of running water compared to the sands and gravels. The sands fall into an intermediate range of deposition. They were primarily deposited in proglacial lakes. Thus, they have undergone enough meltwater transportation to remove some of the LS+SS/SH. The gravels have been deposited by outwash streams, and most samples have lost most of the LS+SS/SH component through the course of longer stream transportation. Gravels are thus enriched in resistant chert.

Heavy Minerals

Weathering shows some influence on the tills (fig. 9). All four surface samples plot well below the 63% line of Am+Ep+Py+Tr. The drift material can show weathering effects at depths to 25 m. Tills 38, 39, and 46 are within this depth. The weathering effect shows the samples with higher percentages of garnet and zircon, which are more stable than amphibole, epidote, pyroxene, and tourmaline. The tills that plot above the 63% line of Am+Ep+Py+Tr demonstrate that little post-depositional change has occurred in these tills. If much weathering had occurred, the unstable minerals would have been removed to a greater extent. Of the subsurface tills, 75% show a composition with an abundance of unstable heavy minerals.

The depositional environment of the sands (fig. 8), proves to be quite different from the tills. The sands have been deposited in proglacial lakes. The sands have a wider distribution of component values. Some weathering and sorting may have taken place during transportation and deposition of the sand samples. The surface samples are weathered to some extent and sands 16 and 17 are the top two core samples from the Marshall County location. Sand 16 is from 8.2-8.5 m, sand 17 is from 25.9-26.0 m. Both of these are from depths in which subtle weathering could occur. Thus they appear to have higher percentages of the more stable components, garnet and zircon. Of the subsurface sands, 20% show a composition with an abundance of unstable heavy minerals.

The gravels (fig. 7) were deposited by outwash streams and show a more centralized distribution by composition than do the tills or sands. The surface gravel values are intermingled with the subsurface gravels. Because of stream action, many of the unstable minerals have been sorted or weathered out during transportation and deposition. This is quite obvious as none of the gravels plot above the 63% Am+Ep+Py+Tr line. Surface gravels 14 and 15 are from Shawnee County, site SN4 (fig. 2). They plot near the center of the diagram, which is a good indication that these gravels were influenced in composition by meltwater streams from the north and streams flowing into the region from the west. A mixing effect occurred in this region. All of the subsurface samples, many of them chert gravels, are from considerable depths, ranging from 53.0-53.9 m at site MS1 to 109.7-112.8 m at site NM7. These are from depths too great to be affected by post-depositional weathering.

CHAPTER VII

CONCLUSIONS

One-hundred-seventeen samples were analyzed for small-pebble and heavy-mineral composition. The samples were obtained from sub-till gravel, Lower Kansas Till, Atchison Formation, Upper Kansas Till, and outwash gravel. The tills and Atchison Formation collectively comprise the Kansas Drift.

On the basis of fifty-one small-pebble analyses from twenty-three localities, the following conclusions can be made: (1) limestone is the most abundant rock, (2) felsic crystalline rocks are the most abundant erratics, (3) quartz, quartzite, felsic crystalline, and mafic crystalline combined are approximately equal to the percentage of sandstone + shale, (4) quartzite is the least abundant rock, constituting about 1% of the samples, and (5) weathering has removed much of the limestone from some surficial and shallow subsurface samples. These results are very similar to those stated by Davis (1951).

On the basis of sixty-six heavy-mineral analyses from seventeen localities, the following conclusions can be made: (1) opaque minerals are the most abundant, (2) garnets and zircon are the most abundant non-opaque minerals, (3) amphiboles, epidote, pyroxenes, and tourmaline are the most abundant unstable minerals, (4) kyanite, rutile, sphene, and spinel are the least abundant unstable minerals, and (5) weathering has removed a considerable percentage of the unstable minerals from the surficial samples and many of the opaque minerals are probably products of weathering.

Geographical location, stratigraphy, and depth are not of great importance in the distribution of the small pebbles and heavy minerals on the diagrams. Post-depositional weathering has severely altered shallow drift composition, and subtle weathering effects reach at least 25 m deep (Aber et al. 1988).

Depositional environment is, aside from weathering, the most important factor. The tills were deposited directly by glacier ice, and contain a considerable percentage of LS+SS/SH and unstable heavy minerals. The sands were primarily deposited in proglacial lakes. Thus, they underwent enough meltwater transportation to remove some of the LS+SS/SH and unstable heavy minerals. The gravels were deposited by outwash streams, and most samples have lost most of the LS+SS/SH and unstable heavy minerals through the longer stream transportation.

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APPENDIX A

LOCATIONS OF SAMPLE SITES BY COUNTY

LE SITE	LOCATION
	NE1/4, Sect. 33, T.3S., R.22E., Doniphan County
	NW1/4, Sect. 15, T.3S., R.22E., Doniphan County
	NW1/4, Sect. 21, T.3S., R.22E., Doniphan County
	NW1/4, Sect. 35, T.4S., R.21E., Doniphan County
	SE1/4, Sect. 24, T.4S., R.21E., Doniphan County
	NW1/4, Sect. 10, T.6S., R.20E., Atchison County
	Center line between SW1/4 and SE1/4, Sect. 2, T.6S., R.20E., Atchison County
	SW1/4, Sect. 9, T.11S., R.15E., Shawnee County
	NE1/4, Sect. 17, T.4S., R.10E., Marshall County
	SW1/4, Sect. 35, T.4S., R.11E., Nemaha County
2	SW1/4, Sect. 35, T.4S., R.11E., Nemaha County
3	SW1/4, Sect. 35, T.4S., R.11E., Nemaha County
4	SW1/4, Sect. 35, T.4S., R.11E., Nemaha County
5	SW1/4, Sect. 35, T.4S., R.11E., Nemaha County
6	NW1/4, Sect. 2, T.5S., R.11E., Nemaha County
7	NW1/4, Sect. 2, T.5S., R.11E., Nemaha County
8	NE1/4, Sect. 35, T.4S., R.11E., Nemaha County
9	NE1/4, Sect. 21, T.4S., R.12E., Nemaha County
M10	NW1/4, Sect. 34, T.4S., R.12E., Nemaha County
M11	NM1/4, Sect. 12, T.5S., R.12E., Nemaha County
M12	NE1/4, Sect. 2, T.4S., R.13E., Nemaha County

SE1/4, Sect. 35, T.4S., R.14E., Nemaha County

Samples from Fremont, Nebraska vicinity

SE1/4, Sect. 8, T.18N., R.9E., Dodge County (Nebraska)

NW1/4, Sect. 34, T.17N., R.8E., Saunders County (Nebraska)

APPENDIX B

SMALL PEBBLE COUNTS

#1 Coarse Chert Gravel (1)
h: Surface

tz	10	2.9
tzite	0	0.0
ic	0	0.0
c	2	0.6
stone	144	41.9
rt	169	49.1
SH	17	4.9
nstone	2	0.6
	344	100.0%

Normalized

Qt-Qtz-Fe-Ma	12	3.5
LS-SS/SH	161	47.1
Chert	169	49.4
	342	100.0%

-#2 Gray Till (2)
th: Surface

rtz	6	2.3
rtzite	1	0.4
sic	36	13.7
ic	24	9.1
estone	130	49.4
rt	22	8.4
/SH	41	15.6
nstone	3	1.1
	263	100.0%

Normalized

Qt-Qtz-Fe-Ma	67	25.8
LS-SS/SH	171	65.8
Chert	22	8.5
	260	100.1%

1-#3 Gray Till (3)
pth: Surface

artz	10	4.7
artzite	1	0.5
lsic	32	15.0
fic	23	11.0
mestone	109	51.7
ert	9	4.3
S/SH	25	11.8
ronstone	2	0.9
	211	99.9%

(1 Pyrite)

Normalized

Qt-Qtz-Fe-Ma	66	31.6
LS-SS/SH	134	64.1
Chert	9	4.3
	209	100.0%

1 Gray Till (4)

: Surface

tz	10	3.3
tzite	4	1.3
ic	49	16.0
c	28	9.2
stone	107	35.0
t	50	16.3
H	51	16.7
stone	7	2.3
	306	100.1%

(1 Coal, 2 Marcasite)

Normalized

Qt-Qtz-Fe-Ma	91	30.4
LS-SS/SH	158	52.8
Chert	50	16.7
	299	99.9%

-#2 Gray Till (5)

th: Surface

tz	2	3.9
tzite	1	2.0
sic	6	11.8
ic	10	19.6
estone	14	27.5
rt	7	13.7
/SH	9	17.6
nstone	2	3.9
	51	100.0%

(1 Marcasite)

Normalized

Qt-Qtz-Fe-Ma	19	38.8
LS-SS/SH	23	46.9
Chert	7	14.3
	49	100.0%

2-#2 Chert Gravel (6)

pth: Surface

artz	27	6.8
artzite	3	0.8
lsic	37	9.4
fic	4	1.0
mestone	31	7.9
ert	275	69.8
/SH	14	3.6
onstone	3	0.8
	394	100.1%

Normalized

Qt-Qtz-Fe-Ma	71	18.2
LS-SS/SH	45	11.5
Chert	275	70.3
	391	100.0%

#1 Tan Sand (7)
h: Surface

tz	4	6.5
tzite	0	0.0
ic	0	0.0
c	0	0.0
stone	36	58.1
rt	16	25.8
SH	5	8.1
stone	1	1.6
	62	100.1%

Normalized

Qt-Qtz-Fe-Ma	4	6.6
LS-SS/SH	41	67.2
Chert	16	26.2
	61	100.0%

-#2 Tan Sand (8)
th: Surface

rtz	5	8.5
rtzite	3	5.1
sic	2	3.4
ic	1	1.7
estone	24	40.7
rt	20	33.9
/SH	2	3.4
onstone	2	3.4
	59	100.1%

Normalized

Qt-Qtz-Fe-Ma	11	19.3
LS-SS/SH	26	45.6
Chert	20	35.1
	57	100.0%

4-#3 Tan Gravel (9)
pth: Surface

artz	26	7.4
artzite	3	0.9
elsic	2	0.6
fic	5	1.4
imestone	228	64.8
hert	60	17.0
S/SH	13	3.7
ronstone	15	4.3
	352	100.1%

Normalized

Qt-Qtz-Fe-Ma	36	10.7
LS-SS/SH	241	71.5
Chert	60	17.8
	337	100.0%

#4 Tan Gravel (10)
h: Surface

tz	14	4.3
tzite	3	0.9
ic	5	1.5
c	11	3.4
stone	233	71.9
t	27	8.3
H	21	6.5
nstone	10	3.1
	324	99.9%

Normalized

Qt-Qtz-Fe-Ma	33	10.5
LS-SS/SH	254	80.9
Chert	27	8.6
	314	100.0%

-#5 Chert Gravel (11)
th: 53.0-53.9 m

rtz	10	2.7
rtzite	9	2.4
lsic	19	5.1
fic	13	3.5
mestone	101	27.0
ert	209	55.9
/SH	12	3.2
onstone	1	0.3
	374	100.1%

(1 Coal)

Normalized

Qt-Qtz-Fe-Ma	51	13.7
LS-SS/SH	113	30.3
Chert	209	56.0
	373	100.0%

S1-#6 Chert Gravel (12)
epth: 56.4-56.7 m

uartz	9	2.9
uartzite	9	2.9
elsic	12	3.9
afic	13	4.2
imestone	98	31.6
hert	157	50.6
S/SH	11	3.5
ronstone	1	0.3
	310	99.9%

Normalized

Qt-Qtz-Fe-Ma	43	13.9
LS-SS/SH	109	35.3
Chert	157	50.8
	309	100.0%

#1 Chert Gravel (13)
h: 107.3-110.3 m

tz	5	1.7
tzite	2	0.7
ic	9	3.0
c	1	0.3
stone	24	8.0
t	248	82.4
H	9	3.0
stone	3	1.0
	301	100.1%

Normalized

Qt-Qtz-Fe-Ma	17	5.7
LS-SS/SH	33	11.1
Chert	248	83.2
	298	100.0%

-#1 Chert Gravel (14)
th: 103.6-105.8 m

rtz	12	3.6
rtzite	0	0.0
sic	4	1.2
ic	3	0.9
estone	8	2.4
rt	290	88.1
/SH	7	2.1
nstone	5	1.5
	329	99.8%

Normalized

Qt-Qtz-Fe-Ma	19	5.9
LS-SS/SH	15	4.6
Chert	290	89.5
	324	100.0%

3-#1 Chert Gravel (15)
pth: 97.5-100.0 m

artz	11	3.2
artzite	9	2.6
lsic	11	3.2
fic	3	0.8
mestone	35	10.0
ert	249	71.3
S/SH	13	3.7
ronstone	18	5.2
	349	100.0%

Normalized

Qt-Qtz-Fe-Ma	34	10.3
LS-SS/SH	48	14.5
Chert	249	75.2
	331	100.0%

#2 Chert Gravel (16)

: 104.5-109.7 m

tz	5	1.5
tzite	6	1.7
ic	4	1.2
c	15	4.4
stone	20	5.8
t	279	81.3
H	5	1.5
stone	9	2.6
	343	100.0%

Normalized

Qt-Qtz-Fe-Ma	30	9.0
LS-SS/SH	25	7.5
Chert	279	83.5
	334	100.0%

-#1 Chert Gravel (17)

th: 104.2-109.7 m

rtz	6	2.4
rtzite	4	1.6
sic	7	2.8
ic	3	1.2
estone	12	4.7
rt	202	79.8
/SH	5	2.0
nstone	14	5.5
	253	100.0%

Normalized

Qt-Qtz-Fe-Ma	20	8.4
LS-SS/SH	17	7.1
Chert	202	84.5
	239	100.0%

6-#5 Chert Gravel (18)

pth: 100.0-100.9 m

artz	8	2.3
artzite	4	1.1
lsic	13	3.7
fic	7	2.0
mestone	26	7.4
ert	268	76.0
/SH	17	4.8
onstone	10	2.8
	353	100.1%

Normalized

Qt-Qtz-Fe-Ma	32	9.3
LS-SS/SH	43	12.5
Chert	268	78.1
	343	99.9%

l Chert Gravel (19)
: 97.5-100.3 m

z	6	2.4
zite	3	1.2
c	3	1.2
	7	2.8
tone	31	12.4
	176	70.4
	15	6.0
tone	9	3.6
	250	100.0%

Normalized

Qt-Qtz-Fe-Ma	19	7.9
LS-SS/SH	46	19.1
Chert	176	73.0
	241	100.0%

-#1 Tan Sand (20)
h: 6.7-6.9 m

tz	10	19.6
tzite	2	3.9
ic	12	23.5
c	8	15.7
stone	3	5.9
t	15	29.4
SH	0	0.0
stone	1	2.0
	51	100.0%

Normalized

Qt-Qtz-Fe-Ma	32	64.0
LS-SS/SH	3	6.0
Chert	15	30.0
	50	100.0%

2-#11 Coarse Gravel (21)
th: 110.0-111.9 m

rtz	9	10.0
rtzite	4	4.4
sic	9	10.0
fic	19	21.1
estone	44	48.9
rt	3	3.3
/SH	0	0.0
onstone	2	2.2
	90	99.9%

Normalized

Qt-Qtz-Fe-Ma	41	46.6
LS-SS/SH	44	50.0
Chert	3	3.4
	88	100.0%

3-#1 Gray Till (22)
pth: 9.2-9.5 m

artz	6	7.8
artzite	1	1.2
lsic	12	15.6
fic	4	5.2
mestone	39	50.6
ert	6	7.8
/SH	5	6.5
onstone	4	5.2
	77	99.9%

(4 Pyrite)

Normalized

Qt-Qtz-Fe-Ma	23	31.5
LS-SS/SH	44	60.3
Chert	6	8.2
	73	100.0%

3-#2 Gray Till (23)
th: 24.7-24.8 m

rtz	9	5.5
rtzite	2	1.2
sic	8	4.9
ic	10	6.1
estone	105	64.0
rt	16	9.8
/SH	6	3.7
onstone	8	4.9
	164	100.1%

(2 Pyrite)

Normalized

Qt-Qtz-Fe-Ma	29	18.6
LS-SS/SH	111	71.1
Chert	16	10.3
	156	100.0%

13-#3 Coarse Sand (24)
pth: 46.9-47.1 m

artz	6	4.8
artzite	4	3.2
lsic	11	8.8
fic	16	12.8
mestone	57	45.6
ert	26	20.8
S/SH	2	1.6
ronstone	3	2.4
	125	100.0%

Normalized

Qt-Qtz-Fe-Ma	37	30.3
LS-SS/SH	59	48.4
Chert	26	21.3
	122	100.0%

#1 Chert Gravel (25)
h: Surface

tz	4	2.6
tzite	1	0.6
ic	0	0.0
c	0	0.0
stone	66	42.3
H	5	3.2
t	80	51.3
stone	0	0.0
	156	100.0%

Normalized

Qt-Qtz-Fe-Ma	5	3.2
LS-SS/SH	71	45.5
Chert	80	51.3
	156	100.0%

-#2 Sand with Pebbles (26)
th: Surface

rtz	6	2.7
rtzite	1	0.4
sic	2	0.9
ic	3	1.3
estone	52	23.2
/SH	19	8.5
rt	141	62.9
onstone	0	0.0
	224	99.9%

Normalized

Qt-Qtz-Fe-Ma	12	5.4
LS-SS/SH	71	31.7
Chert	141	62.9
	224	100.0%

1-#3 Gray Till (27)
pth: Surface

artz	1	0.4
artzite	0	0.0
lsic	9	3.8
fic	1	0.4
mestone	168	71.2
S/SH	53	22.5
hert	2	0.8
ronstone	2	0.8
	236	99.9%

Normalized

Qt-Qtz-Fe-Ma	11	4.7
LS-SS/SH	221	94.4
Chert	2	0.9
	234	100.0%

#4 Gravel lens in Till (28)

h: Surface

tz	8	3.1
tzite	0	0.0
ic	21	8.1
c	19	7.4
stone	138	53.5
H	61	23.6
t	11	4.3
stone	0	0.0
	258	100.0%

Normalized

Qt-Qtz-Fe-Ma	48	18.6
LS-SS/SH	199	77.1
Chert	11	4.3
	258	100.0%

-#5 Gray Till (29)

th: Surface

rtz	5	1.7
rtzite	2	0.7
sic	31	10.4
ic	6	2.0
estone	158	53.0
/SH	75	25.2
rt	16	5.4
nstone	5	1.7
	298	100.1%

Normalized

Qt-Qtz-Fe-Ma	44	15.0
LS-SS/SH	233	79.5
Chert	16	5.5
	293	100.0%

2-#1 Weathered Brown Till (30)

pth: Surface

artz	13	7.1
artzite	3	1.6
lsic	60	32.8
fic	10	5.5
mestone	0	0.0
S/SH	64	35.0
ert	20	10.9
ronstone	13	7.1
	183	100.0%

Normalized

Qt-Qtz-Fe-Ma	86	50.6
LS-SS/SH	64	37.6
Chert	20	11.8
	170	100.0%

-#2 Sandy Pebble Gravel lens (31)

th: Surface

rtz	24	7.9
rtzite	4	1.3
sic	92	30.3
ic	22	7.2
estone	0	0.0
/SH	112	36.8
rt	45	14.8
nstone	5	1.6
	304	99.9%

Normalized

Qt-Qtz-Fe-Ma	142	47.5
LS-SS/SH	112	37.5
Chert	45	15.1
	299	100.1%

3-#1 Sand lens in Till (32)

pth: Surface

artz	19	9.4
artzite	4	2.0
lsic	64	31.7
fic	20	9.9
mestone	0	0.0
/SH	61	30.2
ert	33	16.3
onstone	1	0.5
	202	100.0%

Normalized

Qt-Qtz-Fe-Ma	107	53.2
LS-SS/SH	61	30.3
Chert	33	16.4
	201	99.9%

P3-#2 Brown Till (33)

epth: Surface

uartz	18	7.8
uartzite	6	2.6
elsic	71	30.7
afic	10	4.3
imestone	0	0.0
S/SH	58	25.1
hert	28	12.1
ronstone	40	17.3
	231	99.9%

Normalized

Qt-Qtz-Fe-Ma	105	55.0
LS-SS/SH	58	30.4
Chert	28	14.7
	191	100.1%

#1 Leached Brown Till (34)

: Surface

tz	13	3.9
tzite	1	0.3
ic	34	10.3
c	15	4.5
stone	130	39.4
H	112	33.9
t	7	2.1
stone	18	5.5
	330	99.9%

Normalized

Qt-Qtz-Fe-Ma	63	20.2
LS-SS/SH	242	77.6
Chert	7	2.2
	312	100.0%

-#2 Leached Brown Till (35)

th: Surface

rtz	15	3.7
rtzite	2	0.5
sic	27	6.7
ic	13	3.2
estone	154	38.1
/SH	164	40.6
rt	11	2.7
nstone	18	4.5
	404	100.0%

Normalized

Qt-Qtz-Fe-Ma	57	14.8
LS-SS/SH	318	82.4
Chert	11	2.8
	386	100.0%

5-#1 Brown Till (36)

pth: Surface

artz	3	1.0
artzite	1	0.3
lsic	3	1.0
fic	1	0.3
imestone	195	63.5
S/SH	68	22.1
hert	26	8.5
ronstone	10	3.3
	307	100.0%

Normalized

Qt-Qtz-Fe-Ma	8	2.7
LS-SS/SH	263	88.6
Chert	26	8.8
	297	100.1%

#2 Pebbly Sand (37)
h: Surface

tz	2	0.7
tzite	0	0.0
ic	0	0.0
c	0	0.0
stone	215	71.9
H	63	21.1
t	17	5.7
stone	2	0.7
	299	100.1%

Normalized

Qt-Qtz-Fe-Ma	2	0.7
LS-SS/SH	278	93.6
Chert	17	5.7
	297	100.0%

-#3 Gray Till (38)
th: Surface

rtz	0	0.0
rtzite	0	0.0
sic	4	1.4
fic	2	0.7
estone	199	69.3
/SH	67	23.3
ert	15	5.2
onstone	0	0.0
	287	99.9%

Normalized

Qt-Qtz-Fe-Ma	6	2.1
LS-SS/SH	266	92.7
Chert	15	5.2
	287	100.0%

P5-#4 Brown Till (39)
epth: Surface

uartz	2	0.7
uartzite	0	0.0
elsic	9	3.1
afic	3	1.0
imestone	168	57.7
S/SH	81	27.8
hert	13	4.5
ronstone	15	5.2
	291	100.0%

Normalized

Qt-Qtz-Fe-Ma	14	5.1
LS-SS/SH	249	90.2
Chert	13	4.7
	276	100.0%

#1 Gray Till (40)
h: Surface

rtz	9	2.8
tzite	4	1.3
ic	27	8.5
c	12	3.8
estone	141	44.2
SH	108	33.9
rt	13	4.1
nstone	5	1.6
	319	100.2%

Normalized

Qt-Qtz-Fe-Ma	52	16.6
LS-SS/SH	249	79.3
Chert	13	4.1
	314	100.0%

l-#2 Brown Till (41)
pth: Surface

artz	2	0.7
artzite	2	0.7
lsic	30	9.9
fic	8	2.6
mestone	130	43.2
/SH	92	30.4
ert	26	8.6
onstone	10	3.3
	301	100.1%

Normalized

Qt-Qtz-Fe-Ma	42	14.5
LS-SS/SH	222	76.6
Chert	26	9.0
	290	100.0%

T1-#3 Gray Till (42)
epth: Surface

uartz	2	0.8
uartzite	2	0.8
elsic	21	8.1
afic	15	5.8
imestone	115	44.6
S/SH	82	31.8
hert	14	5.4
ronstone	6	2.3
	257	100.0%

Normalized

Qt-Qtz-Fe-Ma	40	15.9
LS-SS/SH	197	78.5
Chert	14	5.6
	251	100.0%

#4 Brown Till (43)
h: Surface

tz	10	3.0
tzite	2	0.6
ic	39	11.6
c	10	3.0
stone	154	46.1
SH	106	31.5
rt	8	2.4
nstone	5	1.5
	335	100.0%

Normalized

Qt-Qtz-Fe-Ma	61	18.5
LS-SS/SH	260	79.0
Chert	8	2.4
	329	99.9%

-#5 Coarse Sand (44)
pth: Surface

rtz	8	3.1
rtzite	1	0.4
lsic	23	9.0
fic	9	3.5
estone	134	52.3
/SH	62	24.2
ert	10	3.9
onstone	9	3.5
	256	99.9%

Normalized

Qt-Qtz-Fe-Ma	41	16.6
LS-SS/SH	196	79.4
Chert	10	4.0
	247	100.0%

T2-#1 Sandy Gravel (45)
epth: Surface

uartz	9	3.0
uartzite	2	0.7
elsic	34	11.4
afic	8	2.7
imestone	140	47.1
S/SH	81	27.3
hert	22	7.4
ronstone	1	0.3
	297	99.9%

Normalized

Qt-Qtz-Fe-Ma	53	17.9
LS-SS/SH	221	74.7
Chert	22	7.4
	296	100.0%

-#2 Brown Till (46)
th: Surface

rtz	5	1.5
rtzite	3	0.9
sic	24	7.7
ic	2	0.6
estone	162	52.2
/SH	93	29.9
rt	4	1.2
nstone	5	1.5
	310	99.8%

Normalized

Qt-Qtz-Fe-Ma	34	11.1
LS-SS/SH	255	83.6
Chert	4	1.3
	305	100.0%

2-#3 Brown Till (47)
pth: Surface

artz	2	0.6
artzite	3	0.9
lsic	16	5.0
fic	9	2.8
mestone	169	52.8
S/SH	103	32.3
hert	5	1.6
ronstone	11	3.4
	320	100.0%

Normalized

Qt-Qtz-Fe-Ma	30	9.8
LS-SS/SH	272	88.6
Chert	5	1.6
	307	100.0%

01-#1 Gray Till (48)
epth: Surface

uartz	7	2.0
uartzite	6	1.7
elsic	30	8.5
afic	12	3.4
imestone	250	70.8
S/SH	33	9.3
hert	7	2.0
ronstone	8	2.3
	353	100.0%

Normalized

Qt-Qtz-Fe-Ma	55	15.9
LS-SS/SH	283	82.0
Chert	7	2.0
	345	99.9%

l-#1 Gray Till (49)
pth: Surface

artz	16	4.1
artzite	4	1.0
lsic	96	24.4
fic	39	9.9
estone	178	45.2
/SH	26	6.6
ert	16	4.1
onstone	19	4.8
	394	100.1%

Normalized

Qt-Qtz-Fe-Ma	155	41.3
LS-SS/SH	204	54.4
Chert	16	4.3
	375	100.0%

A1-#2 Gravel lens in Till (50)
epth: Surface

uartz	12	3.3
uartzite	1	0.3
elsic	61	16.5
afic	27	7.3
imestone	142	38.8
S/SH	54	14.6
hert	42	11.4
ronstone	27	7.3
	367	100.0%

Normalized

Qt-Qtz-Fe-Ma	101	29.8
LS-SS/SH	196	57.8
Chert	42	12.4
	339	100.0%

A1-#3 Brown Till (51)
epth: Surface

uartz	2	0.9
uartzite	3	1.3
elsic	33	14.7
afic	17	7.6
imestone	141	62.7
S/SH	7	3.1
hert	5	2.2
ronstone	17	7.6
	225	100.1%

Normalized

Qt-Qtz-Fe-Ma	55	26.4
LS-SS/SH	148	71.2
Chert	5	2.4
	208	100.0%

APPENDIX C

HEAVY MINERAL COUNTS

-#1 Coarse Chert Gravel (1)
th: Surface

que	153	53.7
hibole	8	2.8
dote	11	3.9
net	42	14.7
nite	2	0.7
oxene	4	1.4
ile	7	2.5
ene	2	0.7
nel	10	3.5
urmaline	4	1.4
rcon	42	14.7
	285	100.0%

Normalized

Am-Ep-Py-Tr	27	24.3
Garnet	42	37.8
Zircon	42	37.8
	111	99.9%

1-#2 Gray Till (2)
pth: Surface

aque	135	44.1
phibole	22	7.2
idote	11	3.6
rnet	57	18.6
anite	3	1.0
roxene	14	4.6
tile	20	6.5
phene	3	1.0
pinel	7	2.3
ourmaline	10	3.3
ircon	24	7.8
	306	100.0%

Normalized

Am-Ep-Py-Tr	57	41.3
Garnet	57	41.3
Zircon	24	17.4
	138	100.0%

P1-#3 Gray Till (3)
epth: Surface

paque	18	12.0
nphibole	4	2.7
pidote	3	2.0
rnet	46	30.7
anite	2	1.3
roxene	14	9.3
tile	1	0.7
hene	2	1.3
inel	1	0.7
ourmaline	2	1.3
rcon	57	38.0
	150	100.0%

Normalized

Am-Ep-Py-Tr	23	18.3
Garnet	46	36.5
Zircon	57	45.2
	126	100.0%

-#4 Fine Gray Sand (4)
th: Surface

que	44	18.3
hibole	10	4.2
dote	11	4.6
net	52	21.7
nite	3	1.3
oxene	17	7.1
tile	2	0.8
ene	3	1.3
inel	1	0.4
urmaline	4	1.7
rcon	93	38.8
	240	100.2%

Normalized

Am-Ep-Py-Tr	42	22.5
Garnet	52	27.8
Zircon	93	49.7
	187	100.0%

1-#5 Medium Gray Sand (5)
pth: Surface

paque	62	26.1
phibole	2	0.8
pidote	11	4.6
arnet	53	22.3
yanite	2	0.8
yroxene	21	8.8
utile	2	0.8
phene	1	0.4
pinel	1	0.4
ourmaline	7	2.9
ircon	76	31.9
	238	99.8%

Normalized

Am-Ep-Py-Tr	41	24.1
Garnet	53	31.2
Zircon	76	44.7
	170	100.0%

T1-#1 Gray Till (6)
epth: Surface

paque	57	25.1
mphibole	5	2.2
pidote	7	3.1
arnet	46	20.3
yanite	3	1.3
yroxene	22	9.7
utile	0	0.0
phene	1	0.4
pinel	1	0.4
ourmaline	4	1.8
ircon	81	35.7
	227	100.0%

Normalized

Am-Ep-Py-Tr	38	23.0
Garnet	46	27.9
Zircon	81	49.1
	165	100.0%

-#2 Gray Till (7)
th: Surface

que	124	43.4
hibole	7	2.4
dote	5	1.7
net	82	28.7
nite	1	0.3
oxene	16	5.6
ile	0	0.0
ene	0	0.0
nel	0	0.0
urmaline	6	2.1
rcon	45	15.7
	286	99.9%

Normalized

Am-Ep-Py-Tr	34	21.1
Garnet	82	50.9
Zircon	45	28.0
	161	100.0%

l-#3 Fine Tan Sand (8)
pth: Surface

aque	77	26.7
phibole	4	1.4
idote	3	1.0
rnet	80	27.8
yanite	0	0.0
yroxene	23	8.0
utile	2	0.7
phene	0	0.0
pinel	1	0.3
ourmaline	2	0.7
ircon	96	33.3
	288	99.9%

Normalized

Am-Ep-Py-Tr	32	15.4
Garnet	80	38.5
Zircon	96	46.2
	208	100.1%

T1-#4 Fine Tan Sand (9)
epth: Surface

paque	49	20.1
mphibole	5	2.0
pidote	5	2.0
arnet	64	26.2
yanite	0	0.0
yroxene	20	8.2
utile	1	0.4
phene	1	0.4
pinel	0	0.0
ourmaline	5	2.0
ircon	94	38.5
	244	99.8%

Normalized

Am-Ep-Py-Tr	35	18.1
Garnet	64	33.2
Zircon	94	48.7
	193	100.0%

-#1 Fine Tan Sand (10)

th: Surface

que	37	15.5
hibole	9	3.8
dote	2	0.8
rnet	97	40.6
anite	0	0.0
roxene	14	5.9
tile	4	1.7
hene	1	0.4
inel	1	0.4
urmaline	6	2.5
rcon	68	28.5
	239	100.1%

Normalized

Am-Ep-Py-Tr	31	15.8
Garnet	97	49.5
Zircon	68	34.7
	196	100.0%

T2-#2 Chert Gravel (11)

epth: Surface

paque	97	41.5
mphibole	22	9.4
pidote	16	6.8
arnet	38	16.2
yanite	1	0.4
yroxene	26	11.1
utile	3	1.3
phene	0	0.0
pinel	5	2.1
ourmaline	5	2.1
ircon	21	9.0
	234	99.9%

Normalized

Am-Ep-Py-Tr	69	53.9
Garnet	38	29.7
Zircon	21	16.4
	128	100.0%

N4-#1 Tan Sand (12)

epth: Surface

paque	69	30.7
mphibole	2	0.9
pidote	7	3.1
arnet	55	24.4
yanite	0	0.0
yroxene	54	24.0
utile	1	0.4
phene	0	0.0
pinel	1	0.4
ourmaline	3	1.3
ircon	33	14.7
	225	99.9%

Normalized

Am-Ep-Py-Tr	66	42.9
Garnet	55	35.7
Zircon	33	21.4
	154	100.0%

4-#2 Tan Sand (13)
pth: Surface

aque	29	12.2
phibole	5	2.1
idote	6	2.5
rnet	80	33.6
anite	0	0.0
roxene	35	14.7
tile	2	0.8
hene	0	0.0
inel	1	0.4
ourmaline	4	1.7
ircon	76	31.9
	238	99.9%

Normalized

Am-Ep-Py-Tr	50	24.3
Garnet	80	38.8
Zircon	76	36.9
	206	100.0%

N4-#3 Tan Gravel (14)
epth: Surface

paque	89	35.6
mphibole	1	0.4
pidote	14	5.6
arnet	55	22.0
yanite	0	0.0
yroxene	47	18.8
utile	7	2.8
phene	1	0.4
pinel	0	0.0
ourmaline	4	1.6
ircon	32	12.8
	250	100.0%

Normalized

Am-Ep-Py-Tr	66	43.1
Garnet	55	35.9
Zircon	32	20.9
	153	99.9%

N4-#4 Tan Gravel (15)
epth: Surface

paque	142	49.5
mphibole	1	0.3
pidote	11	3.8
arnet	46	16.0
yanite	0	0.0
yroxene	31	10.8
utile	9	3.1
phene	2	0.7
pinel	2	0.7
ourmaline	5	1.7
ircon	38	13.2
	287	99.8%

Normalized

Am-Ep-Py-Tr	48	36.4
Garnet	46	34.8
Zircon	38	28.8
	132	100.0%

-#2 Tan Sand (13)
th: Surface

que	29	12.2
hibole	5	2.1
dote	6	2.5
rnet	80	33.6
nite	0	0.0
roxene	35	14.7
tile	2	0.8
hene	0	0.0
inel	1	0.4
urmaline	4	1.7
rcon	76	31.9
	238	99.9%

Normalized

Am-Ep-Py-Tr	50	24.3
Garnet	80	38.8
Zircon	76	36.9
	206	100.0%

4-#3 Tan Gravel (14)
pth: Surface

paque	89	35.6
mphibole	1	0.4
pidote	14	5.6
arnet	55	22.0
yanite	0	0.0
yroxene	47	18.8
utile	7	2.8
phene	1	0.4
pinel	0	0.0
ourmaline	4	1.6
ircon	32	12.8
	250	100.0%

Normalized

Am-Ep-Py-Tr	66	43.1
Garnet	55	35.9
Zircon	32	20.9
	153	99.9%

SN4-#4 Tan Gravel (15)
Depth: Surface

Opaque	142	49.5
Amphibole	1	0.3
Epidote	11	3.8
Garnet	46	16.0
Kyanite	0	0.0
Pyroxene	31	10.8
Rutile	9	3.1
Sphene	2	0.7
Spinel	2	0.7
Tourmaline	5	1.7
Zircon	38	13.2
	287	99.8%

Normalized

Am-Ep-Py-Tr	48	36.4
Garnet	46	34.8
Zircon	38	28.8
	132	100.0%

-#1 Fine Tan Sand (16)
th: 8.2-8.5 m

que	71	28.2
hibole	12	4.8
dote	9	3.6
net	51	20.2
nite	2	0.8
oxene	14	5.6
ile	2	0.8
ene	0	0.0
nel	7	2.8
rmaline	7	2.8
rcon	77	30.6
	252	100.2%

Normalized

Am-Ep-Py-Tr	42	24.7
Garnet	51	30.0
Zircon	77	45.3
	170	100.0%

1-#2 Fine Tan Sand (17)
pth: 25.9-26.0 m

aque	34	12.4
phibole	20	7.3
idote	11	4.0
rnet	76	27.7
anite	5	1.8
roxene	25	9.1
tile	4	1.5
phene	0	0.0
pinel	0	0.0
ourmaline	3	1.1
ircon	96	35.0
	274	99.9%

Normalized

Am-Ep-Py-Tr	59	25.5
Garnet	76	32.9
Zircon	96	41.6
	231	100.0%

MS1-#3 Gray Silt (18)
Depth: 35.0-35.3 m

Opaque	11	4.1
Amphibole	4	1.5
Epidote	5	1.9
Garnet	101	37.8
Kyanite	3	1.1
Pyroxene	32	12.0
Rutile	1	0.4
Sphene	0	0.0
Spinel	0	0.0
Tourmaline	3	1.1
Zircon	107	40.1
	267	100.0%

Normalized

Am-Ep-Py-Tr	44	17.5
Garnet	101	40.1
Zircon	107	42.5
	252	100.1%

-#4 Fine Tan Sand (19)
th: 48.1-48.3 m

que	99	38.1
hibole	18	6.9
dote	6	2.3
rnet	59	22.7
nite	0	0.0
roxene	15	5.8
tile	2	0.8
hene	1	0.4
inel	4	1.5
urmaline	7	2.7
rcon	49	18.8
	260	100.0%

Normalized

Am-Ep-Py-Tr	46	29.9
Garnet	59	38.3
Zircon	49	31.8
	154	100.0%

1-#5 Chert Gravel (20)
pth: 53.0-53.9 m

paque	51	21.1
mphibole	8	3.3
pidote	10	4.1
arnet	57	23.6
yanite	0	0.0
yroxene	16	6.6
utile	1	0.4
phene	2	0.8
pinel	4	1.7
ourmaline	7	2.9
ircon	86	35.5
	242	100.0%

Normalized

Am-Ep-Py-Tr	41	22.3
Garnet	57	31.0
Zircon	86	46.7
	184	100.0%

S1-#6 Chert Gravel (21)
epth: 56.4-56.7 m

paque	27	9.9
mphibole	10	3.7
pidote	12	4.4
arnet	104	38.2
yanite	2	0.7
yroxene	33	12.1
utile	1	0.4
phene	0	0.0
pinel	0	0.0
ourmaline	5	1.8
ircon	78	28.7
	272	99.9%

Normalized

Am-Ep-Py-Tr	60	24.8
Garnet	104	43.0
Zircon	78	32.2
	242	100.0%

-#7 Fine Gray Sand (22)
th: 58.2-58.4 m

que	207	60.2
hibole	8	2.3
dote	10	2.9
rnet	31	9.0
nite	0	0.0
roxene	15	4.4
tile	0	0.0
hene	0	0.0
inel	9	2.6
urmaline	15	4.4
rcon	49	14.2
	344	100.0%

Normalized

Am-Ep-Py-Tr	48	37.5
Garnet	31	24.2
Zircon	49	38.3
	128	100.0%

M1-#1 Gray Chert Gravel (23)
epth: 107.3-110.3 m

paque	168	53.3
mphibole	10	3.2
pidote	11	3.5
arnet	40	12.7
yanite	0	0.0
yroxene	28	8.9
utile	9	2.9
phene	0	0.0
pinel	8	2.5
Tourmaline	7	2.2
Zircon	34	10.8
	315	100.0%

Normalized

Am-Ep-Py-Tr	56	43.1
Garnet	40	30.8
Zircon	34	26.2
	130	100.1%

NM2-#1 Gray Chert Gravel (24)
Depth: 103.6-105.8 m

Opaque	132	51.8
Amphibole	12	4.7
Epidote	12	4.7
Garnet	25	9.8
Kyanite	0	0.0
Pyroxene	24	9.4
Rutile	6	2.4
Sphene	0	0.0
Spinel	4	1.6
Tourmaline	5	2.0
Zircon	35	13.7
	255	100.1%

Normalized

Am-Ep-Py-Tr	53	46.9
Garnet	25	22.1
Zircon	35	31.0
	113	100.0%

-#1 Gray Chert Gravel (25)

th: 97.5-100.0 m

que	112	48.1
phibole	7	3.0
idote	10	4.3
rnet	22	9.4
anite	0	0.0
roxene	33	14.2
tile	1	0.4
hene	1	0.4
inel	2	0.9
urmaline	5	2.1
rcon	40	17.2
	233	100.0%

Normalized

Am-Ep-Py-Tr	55	47.0
Garnet	22	18.8
Zircon	40	34.2
	117	100.0%

M3-#2 Gray Chert Gravel (26)

epth: 104.5-109.7 m

paque	157	57.1
mphibole	14	5.1
pidote	9	3.3
arnet	33	12.0
yanite	0	0.0
yroxene	23	8.4
utile	4	1.5
phene	0	0.0
pinel	1	0.4
ourmaline	9	3.3
ircon	25	9.1
	275	100.2%

Normalized

Am-Ep-Py-Tr	55	48.7
Garnet	33	29.2
Zircon	25	22.1
	113	100.0%

NM4-#1 Chert Gravel (27)

Depth: 104.2-109.7 m

Opaque	93	38.9
Amphibole	12	5.0
Epidote	10	4.2
Garnet	52	21.8
Kyanite	0	0.0
Pyroxene	19	7.9
Rutile	2	0.8
Sphene	1	0.4
Spinel	2	0.8
Tourmaline	3	1.3
Zircon	45	18.8
	239	99.9%

Normalized

Am-Ep-Py-Tr	44	31.2
Garnet	52	36.9
Zircon	45	31.9
	141	100.0%

-#1 Medium Gray Sand (28)
th: 91.4-93.0 m

que	115	45.5
hibole	31	12.3
idote	18	7.1
rnet	38	15.0
anite	0	0.0
roxene	20	7.9
tile	1	0.4
hene	1	0.4
inel	1	0.4
urmaline	12	4.7
rcon	16	6.3
	253	100.0%

Normalized

Am-Ep-Py-Tr	81	60.0
Garnet	38	28.1
Zircon	16	11.9
	135	100.0%

M5-#2 Medium Gray Sand (29)
epth: 97.5-98.5 m

paque	109	46.0
mphibole	24	10.1
pidote	11	4.6
arnet	28	11.8
yanite	1	0.4
yroxene	13	5.5
utile	1	0.4
phene	0	0.0
pinel	10	4.2
ourmaline	12	5.1
ircon	28	11.8
	237	99.9%

Normalized

Am-Ep-Py-Tr	60	51.7
Garnet	28	24.1
Zircon	28	24.1
	116	99.9%

NM6-#1 Medium Gray Sand (30)
Depth: 85.3-86.9 m

Opaque	157	53.2
Amphibole	19	6.4
Epidote	18	6.1
Garnet	35	11.9
Kyanite	0	0.0
Pyroxene	23	7.8
Rutile	1	0.3
Sphene	0	0.0
Spinel	4	1.4
Tourmaline	14	4.7
Zircon	24	8.1
	295	99.9%

Normalized

Am-Ep-Py-Tr	74	55.6
Garnet	35	26.3
Zircon	24	18.0
	133	99.9%

M6-#2 Medium Gray Sand (31)

epth: 86.9-89.9 m

paque	173	56.9
mphibole	19	6.3
pidote	21	6.9
arnet	30	9.9
yanite	0	0.0
yroxene	18	5.9
utile	0	0.0
phene	0	0.0
pinel	2	0.7
ourmaline	7	2.3
ircon	34	11.2
	304	100.1%

Normalized

Am-Ep-Py-Tr	65	50.4
Garnet	30	23.3
Zircon	34	26.4
	129	100.1%

M6-#3 Medium Gray Sand (32)

epth: 91.4-93.0 m

paque	165	57.3
mphibole	26	9.0
pidote	18	6.3
arnet	28	9.7
yanite	0	0.0
yroxene	22	7.6
utile	3	1.0
phene	0	0.0
pinel	3	1.0
ourmaline	5	1.7
ircon	18	6.3
	288	99.9%

Normalized

Am-Ep-Py-Tr	71	60.7
Garnet	28	23.9
Zircon	18	15.4
	117	100.0%

M6-#4 Medium Gray Sand (33)

epth: 97.8-100.0 m

paque	173	54.9
mphibole	18	5.7
pidote	17	5.4
arnet	32	10.2
yanite	0	0.0
yroxene	21	6.7
utile	4	1.3
phene	0	0.0
pinel	2	0.6
ourmaline	16	5.1
ircon	32	10.2
	315	100.1%

Normalized

Am-Ep-Py-Tr	72	52.9
Garnet	32	23.5
Zircon	32	23.5
	136	99.9%

M6-#5 Gray Chert Gravel (34)
epth: 100.0-100.9 m

paque	157	54.0
mphibole	27	9.3
pidote	21	7.2
arnet	34	11.7
yanite	2	0.7
yroxene	17	5.8
utile	3	1.0
Sphene	0	0.0
Spinel	0	0.0
Tourmaline	10	3.4
ircon	20	6.9
	291	100.0%

Normalized

Am-Ep-Py-Tr	75	58.1
Garnet	34	26.4
Zircon	20	15.5
	129	100.0%

M7-#1 Gray Chert Gravel (35)
epth: 109.7-112.8 m

paque	189	63.4
mphibole	18	6.0
pidote	11	3.7
arnet	33	11.1
yanite	0	0.0
yroxene	17	5.7
utile	0	0.0
phene	0	0.0
pinel	1	0.3
ourmaline	8	2.7
ircon	21	7.0
	298	99.9%

Normalized

Am-Ep-Py-Tr	54	50.0
Garnet	33	30.6
Zircon	21	19.4
	108	100.0%

M8-#1 Chert Gravel (36)
epth: 97.5-100.3 m

paque	155	51.7
mphibole	23	7.7
pidote	20	6.7
arnet	25	8.3
yanite	0	0.0
yroxene	34	11.3
utile	0	0.0
phene	0	0.0
pinel	0	0.0
ourmaline	11	3.7
ircon	32	10.7
	300	100.1%

Normalized

Am-Ep-Py-Tr	88	60.7
Garnet	25	17.2
Zircon	32	22.1
	145	100.0%

M9-#1 Fine Tan Sand (37)
epth: 2.5-2.7 m

paque	96	38.7
mphibole	16	6.5
pidote	34	13.7
arnet	54	21.8
yanite	0	0.0
yroxene	12	4.8
utile	2	0.8
phene	0	0.0
pinel	0	0.0
ourmaline	8	3.2
ircon	26	10.5
	248	100.0%

Normalized

Am-Ep-Py-Tr	70	46.7
Garnet	54	36.0
Zircon	26	17.3
	150	100.0%

M9-#2 Tan-Gray Till (38)
epth: 4.0-4.4 m

paque	67	28.8
mphibole	24	10.3
pidote	35	15.0
arnet	46	19.7
yanite	0	0.0
yroxene	18	7.7
utile	0	0.0
phene	0	0.0
pinel	1	0.4
ourmaline	7	3.0
ircon	35	15.0
	233	99.9%

Normalized

Am-Ep-Py-Tr	84	50.9
Garnet	46	27.9
Zircon	35	21.2
	165	100.0%

M9-#3 Oxidiz. Tan Till (39)
epth: 12.5-13.0 m

paque	137	53.5
mphibole	14	5.5
pidote	21	8.2
arnet	38	14.8
yanite	0	0.0
yroxene	4	1.6
utile	0	0.0
phene	0	0.0
pinel	0	0.0
ourmaline	9	3.5
ircon	33	12.9
	256	100.1%

Normalized

Am-Ep-Py-Tr	48	40.3
Garnet	38	31.9
Zircon	33	27.7
	119	99.9%

M9-#4 Gray Till (40)
epth: 22.1-22.4 m

paque	119	41.5
mphibole	41	14.3
pidote	22	7.7
arnet	29	10.1
yanite	0	0.0
yroxene	31	10.8
utile	15	5.2
phene	0	0.0
pinel	0	0.0
ourmaline	10	3.5
ircon	20	7.0
	287	100.1%

Normalized

Am-Ep-Py-Tr	104	68.0
Garnet	29	19.0
Zircon	20	13.1
	153	100.1%

M9-#5 Gray Till (41)
epth: 40.2-40.5 m

paque	170	57.6
mphibole	21	7.1
pidote	19	6.4
arnet	28	9.5
yanite	0	0.0
yroxene	29	9.8
utile	4	1.4
phene	0	0.0
pinel	0	0.0
ourmaline	10	3.4
ircon	14	4.7
	295	99.9%

Normalized

Am-Ep-Py-Tr	79	65.3
Garnet	28	23.1
Zircon	14	11.6
	121	100.0%

M9-#6 Fine Gray Sand (42)
epth: 57.9-59.4 m

paque	113	45.9
mphibole	13	5.3
pidote	30	12.2
arnet	45	18.3
yanite	1	0.4
yroxene	6	2.4
utile	1	0.4
phene	0	0.0
pinel	1	0.4
ourmaline	7	2.8
ircon	29	11.8
	246	99.9%

Normalized

Am-Ep-Py-Tr	56	43.1
Garnet	45	34.6
Zircon	29	22.3
	130	100.0%

19-#7 Gray Till (43)
epth: 77.9-78.3 m

paque	95	36.3
nphibole	30	11.5
oidote	32	12.2
arnet	51	19.5
yanite	2	0.8
yroxene	5	1.9
utile	1	0.4
phene	0	0.0
oinel	0	0.0
ourmaline	17	6.5
ircon	29	11.1
	262	100.2%

Normalized

Am-Ep-Py-Tr	84	51.2
Garnet	51	31.1
Zircon	29	17.7
	164	100.0%

19-#8 Gray Till (44)
epth: 85.6-85.8 m

paque	149	56.0
nphibole	6	2.3
oidote	14	5.3
arnet	43	16.2
yanite	1	0.4
yroxene	16	6.0
utile	0	0.0
phene	0	0.0
oinel	0	0.0
ourmaline	7	2.6
ircon	30	11.3
	266	100.1%

Normalized

Am-Ep-Py-Tr	43	37.1
Garnet	43	37.1
Zircon	30	25.9
	116	100.1%

110-#1 Tannish-Gray Till (45)
epth: 3.1-3.7 m

paque	79	34.8
nphibole	30	13.2
oidote	33	14.5
arnet	24	10.6
yanite	0	0.0
yroxene	26	11.5
utile	4	1.8
phene	0	0.0
oinel	1	0.4
ourmaline	12	5.3
ircon	18	7.9
	227	100.0%

Normalized

Am-Ep-Py-Tr	101	70.6
Garnet	24	16.8
Zircon	18	12.6
	143	100.0%

10-#2 Gray Till (46)
pth: 16.5-16.8 m

aque	183	58.3
phibole	8	2.5
idote	32	10.2
rnet	40	12.7
anite	0	0.0
roxene	22	7.0
tile	0	0.0
hene	0	0.0
inel	0	0.0
urmaline	5	1.6
rcon	24	7.6
	314	99.9%

Normalized

Am-Ep-Py-Tr	67	51.1
Garnet	40	30.5
Zircon	24	18.3
	131	99.9%

10-#3 Gray Till (47)
pth: 46.5-46.9 m

aque	168	53.0
phibole	20	6.3
idote	27	8.5
rnet	36	11.4
anite	0	0.0
roxene	18	5.7
tile	10	3.2
hene	1	0.3
inel	0	0.0
urmaline	24	7.6
rcon	13	4.1
	317	100.1%

Normalized

Am-Ep-Py-Tr	89	64.5
Garnet	36	26.1
Zircon	13	9.4
	138	100.0%

10-#4 Gray Till (48)
pth: 50.7-51.1 m

aque	128	54.0
phibole	37	15.6
idote	14	5.9
rnet	10	4.2
anite	0	0.0
roxene	24	10.1
tile	1	0.4
hene	0	0.0
inel	0	0.0
urmaline	16	6.8
rcon	7	3.0
	237	100.0%

Normalized

Am-Ep-Py-Tr	91	84.3
Garnet	10	9.3
Zircon	7	6.5
	108	100.1%

10-#5 Gray Till (49)
pth: 71.3-71.6 m

aque	110	49.5
phibole	19	8.6
idote	22	9.9
rnet	23	10.4
anite	0	0.0
roxene	26	11.7
tile	5	2.3
hene	0	0.0
inel	1	0.5
urmaline	13	5.9
rcon	3	1.4
	222	100.2%

Normalized

Am-Ep-Py-Tr	80	75.5
Garnet	23	21.7
Zircon	3	2.8
	106	100.0%

10-#6 Gray Till (50)
pth: 100.1-100.4 m

aque	115	43.2
phibole	39	14.7
idote	23	8.6
rnet	31	11.7
anite	1	0.4
roxene	20	7.5
tile	6	2.3
hene	0	0.0
inel	0	0.0
urmaline	23	8.6
rcon	8	3.0
	266	100.0%

Normalized

Am-Ep-Py-Tr	105	72.9
Garnet	31	21.5
Zircon	8	5.6
	144	100.0%

11-#1 Gray Till (51)
pth: 7.3-7.5 m

aque	93	40.8
phibole	49	21.5
idote	15	6.6
rnet	22	9.6
anite	0	0.0
roxene	12	5.3
tile	0	0.0
hene	1	0.4
inel	0	0.0
urmaline	26	11.4
rcon	10	4.4
	228	100.0%

Normalized

Am-Ep-Py-Tr	102	76.1
Garnet	22	16.4
Zircon	10	7.5
	134	100.0%

ll-#2 Gray Till (52)
pth: 20.3-20.9 m

aque	148	56.9
phibole	16	6.2
idote	18	6.9
rnet	27	10.4
anite	1	0.4
roxene	22	8.5
tile	4	1.5
hene	0	0.0
inel	0	0.0
urmaline	14	5.4
rcon	10	3.8
	260	100.0%

Normalized

Am-Ep-Py-Tr	70	65.4
Garnet	27	25.2
Zircon	10	9.3
	107	99.9%

ll-#3 Gray Till (53)
pth: 21.2-21.3 m

aque	129	42.9
phibole	39	13.0
idote	24	8.0
rnet	38	12.6
anite	2	0.7
roxene	28	9.3
tile	4	1.3
hene	0	0.0
inel	1	0.3
urmaline	20	6.6
rcon	16	5.3
	301	100.0%

Normalized

Am-Ep-Py-Tr	111	67.3
Garnet	38	23.0
Zircon	16	9.7
	165	100.0%

ll-#4 Gray Till (54)
pth: 46.9-47.2 m

aque	67	28.5
phibole	52	22.1
idote	8	3.4
rnet	27	11.5
anite	2	0.9
roxene	15	6.4
tile	3	1.3
hene	0	0.0
inel	0	0.0
urmaline	48	20.4
rcon	13	5.5
	235	100.0%

Normalized

Am-Ep-Py-Tr	123	75.5
Garnet	27	16.6
Zircon	13	8.0
	163	100.1%

ill-#5 Gray Till (55)
pth: 62.0-62.1 m

aque	184	55.9
phibole	27	8.2
idote	29	8.8
rnet	34	10.3
anite	0	0.0
roxene	28	8.5
tile	0	0.0
hene	0	0.0
inel	0	0.0
urmaline	12	3.6
rcon	15	4.6
	329	99.9%

Normalized

Am-Ep-Py-Tr	96	66.2
Garnet	34	23.4
Zircon	15	10.3
	145	99.9%

12-#1 Fine Tan Sand (56)
pth: 6.7-6.9 m

aque	158	53.0
phibole	21	7.0
idote	27	9.1
rnet	47	15.8
anite	1	0.3
roxene	10	3.4
tile	1	0.3
hene	1	0.3
inel	0	0.0
urmaline	10	3.4
rcon	22	7.4
	298	100.0%

Normalized

Am-Ep-Py-Tr	68	49.6
Garnet	47	34.3
Zircon	22	16.1
	137	100.0%

12-#2 Tan Sand (57)
pth: 7.2-7.5 m

aque	128	50.6
phibole	17	6.7
idote	32	12.6
rnet	33	13.0
anite	0	0.0
roxene	12	4.7
tile	1	0.4
hene	0	0.0
inel	0	0.0
urmaline	12	4.7
rcon	18	7.1
	253	99.8%

Normalized

Am-Ep-Py-Tr	73	58.9
Garnet	33	26.6
Zircon	18	14.5
	124	100.0%

12-#3 Gray-Tan Silty Clay (58)
pth: 19.0-19.3 m

aque	78	28.7
phibole	63	23.2
idote	33	12.1
rnet	31	11.4
anite	3	1.1
roxene	17	6.3
tile	0	0.0
hene	0	0.0
inel	0	0.0
urmaline	22	8.1
rcon	25	9.2
	272	100.1%

Normalized

Am-Ep-Py-Tr	135	70.7
Garnet	31	16.2
Zircon	25	13.1
	191	100.0%

12-#4 Gray Silty Clay (59)
pth: 19.8-20.1 m

aque	176	55.5
phibole	38	12.0
idote	30	9.5
rnet	19	6.0
anite	1	0.3
roxene	21	6.6
tile	4	1.3
hene	0	0.0
inel	0	0.0
urmaline	16	5.0
rcon	12	3.8
	317	100.0%

Normalized

Am-Ep-Py-Tr	105	77.2
Garnet	19	14.0
Zircon	12	8.8
	136	100.0%

12-#5 Gray-Tan Silty Sand (60)
pth: 33.2-33.4 m

aque	93	38.1
phibole	49	20.1
idote	29	11.9
rnet	18	7.4
anite	0	0.0
roxene	14	5.7
tile	5	2.0
hene	0	0.0
inel	0	0.0
urmaline	21	8.6
rcon	15	6.1
	244	99.9%

Normalized

Am-Ep-Py-Tr	113	77.4
Garnet	18	12.3
Zircon	15	10.3
	146	100.0%

I12-#6 Gray Till (61)
pth: 41.0-41.5 m

aque	120	50.8
phibole	34	14.4
idote	27	11.4
rnet	20	8.5
anite	0	0.0
roxene	15	6.4
tile	0	0.0
hene	0	0.0
inel	0	0.0
urmaline	7	3.0
rcon	13	5.5
	236	100.0%

Normalized

Am-Ep-Py-Tr	83	71.6
Garnet	20	17.2
Zircon	13	11.2
	116	100.0%

I12-#7 Coarse Tan Sand (62)
pth: 42.7-42.8 m

aque	244	67.2
phibole	20	5.5
idote	19	5.2
rnet	31	8.5
anite	1	0.3
roxene	20	5.5
tile	2	0.6
hene	2	0.6
inel	1	0.3
urmaline	10	2.8
rcon	13	3.6
	363	100.1%

Normalized

Am-Ep-Py-Tr	69	61.1
Garnet	31	27.4
Zircon	13	11.5
	113	100.0%

I12-#8 Coarse Tan Sand (63)
pth: 43.0-43.3 m

aque	136	52.9
phibole	32	12.5
idote	22	8.6
rnet	19	7.4
anite	1	0.4
roxene	20	7.8
tile	1	0.4
hene	0	0.0
inel	0	0.0
urmaline	17	6.6
rcon	9	3.5
	257	100.1%

Normalized

Am-Ep-Py-Tr	91	76.5
Garnet	19	16.0
Zircon	9	7.6
	119	100.1%

12-#9 Gray Till (64)
epth: 59.0-59.1 m

paque	136	52.1
nphibole	18	6.9
pidote	30	11.5
arnet	35	13.4
yanite	0	0.0
yroxene	20	7.7
utile	3	1.1
phene	0	0.0
pinel	0	0.0
ourmaline	11	4.2
ircon	8	3.1
	261	100.0%

Normalized

Am-Ep-Py-Tr	79	64.8
Garnet	35	28.7
Zircon	8	6.6
	122	100.1%

12-#10 Gray Till (65)
epth: 78.0-78.3 m

paque	132	55.2
nphibole	21	8.8
pidote	22	9.2
arnet	20	8.4
yanite	0	0.0
yroxene	14	5.9
utile	2	0.8
phene	0	0.0
pinel	0	0.0
ourmaline	15	6.3
rcon	13	5.4
	239	100.0%

Normalized

Am-Ep-Py-Tr	72	68.6
Garnet	20	19.0
Zircon	13	12.4
	105	100.0%

12-#11 Coarse Gravel (66)
epth: 110.0-111.9 m

paque	222	65.3
nphibole	19	5.6
pidote	21	6.2
arnet	37	10.9
yanite	1	0.3
yroxene	17	5.0
utile	1	0.3
phene	0	0.0
pinel	0	0.0
ourmaline	12	3.5
rcon	10	2.9
	340	100.0%

Normalized

Am-Ep-Py-Tr	69	59.5
Garnet	37	31.9
Zircon	10	8.6
	116	100.0%